# REVIEW OF ECOLOGY OF MALARIA VECTORS IN THE WHO EASTERN MEDITERRANEAN REGION

by

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INTRODUCTION

The paper aims at reviewing the recent knowledge and the ecology of malaria vectors existing in the area designated by WHO as the Eastern Mediterranean Region with special reference to technical problems. Previous information can be found in older literature, such as Leeson et al. (1950), Horsfall (1955) and Wattingly & Knight (1956). The present review mainly covers the principal and some additional malaria vectors where information is available from published and unpublished reports of countries having malaria eradication or a control programme underway. Unless relevant, vectors in countries whose programmes are in the maintenance phase, namely Israel and Lebanon, or where malaria has been eradicated as in Cyprus, are not included in the present review since the vector status in such areas is out of the scope of this paper. When sufficient information from specific vigilance observations is available, a paper should be developed aiming at reviewing the ecology of the previous malaria vectors in countries under maintenance or where malaria eradication has been achieved, with special reference to vulnerability and receptivity.

For convenience, vectors dealt with in this review are not arranged in alphabetical order since the region under discussion embraces areas having fauna of three Zoogeographical Regions, namely the Ethiopian, the Palearctic and the Oriental Regions. Thus the review follows as far as possible this sequence, i.e., commencing with vectors occurring in the southernmost part of the region to northern and north-eastern areas.

1. Anopheles gambiae Giles

This is the most important vector of the Ethiopian Zoogeographical Region. In Ethiopia, Somalia, Sudan, Saudi Arabia, South Yemen and Yemen, A. gambiae in riverine areas or areas with permanent sources of water, can be found throughout the year though in very much reduced density during the dry season. Even in areas with limited sources of water, as in Somalia, Saudi Arabia and Sudan, A. gambiae can persist throughout the dry season in a very low density, breeding in the ecologically most suitable niches. These may be termed "mother foci" from which A. gambiae during the rainy season spreads to the surrounding areas which were dry during the arid season. According to Davidson (1966) species B is the only member of the A. gambiae complex which has so far been identified from Saudi Arabia, South Yemen, Sudan and Ethiopia, although there is a single record of species C from Ethiopia (Davidson, personal communication). In climatically favourable years, severe malaria epidemics may develop as observed during 1950-1951 and during 1957-1958 in Saudi Arabia.

In 1958, Fontaine et al. (1961) reported an epidemic in Ethiopia which struck areas at altitudes ranging between 1600 to 2150 metres and indicated that A. gambiae was the only vector involved. The main precipitating cause were the unusual weather conditions in that year as rainfall exceeded all records of previous years while temperature and humidity were abnormally high. Working in an unsprayed area near Nazareth at an altitude of 1600 to 1800 metres in 1964-1965, where the parasite rate ranged between 2.8 and 31.9%, Rishikesh (1960) reported sporozoite rates as low as 0.11-0.31% in 4513 A. gambiae females dissected. A review of anopheline mosquitoes in Ethiopia by O'Connor (1967) quotes many negative results of dissections of A. gambiae carried out by several workers in different parts of the country, with the exception of one record of higher gland infections, given as three in 100 A. gambiae dissected in Welo Province by Rice 1955-1956.

In the area under attack phase of the malaria eradication programme of Ethiopia where operations commenced in 1966-1967, A. gambiae house-resting and biting densities have been much reduced, except in instances when operational defects, mainly related to human ecology, were involved. Jolivet1 reported that some A. gambiae were found resting in a sugar-cane

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plantation near breeding places during day-time, but no details on the density and the abdominal stages were given. From observations made in Zareeth, Rishikesh (1966) concluded that the species is highly endophilic. His data of the blood digestion stages of house-resting populations suggest though that a proportion of females leaves the indoor resting shelter before the completion of the gonotrophic cycle. However, box shelters used for sampling outside resting populations, did not yield any significant number of *A. gambiae*.

Recently outdoor resting of species B was observed by Haridi (1972a) during July-October 1967 in Kheshm El Girba area, Kassala Province, Sudan. He describes the area of observation as having been under DDT house spraying since 1964 and a high incidence of malaria was recorded during the above-mentioned period. Of 432 females collected from outside natural shelters during September-October 1967, 57% were bloodfed. The fed:gravid ratio was 2:1. In precipitin tests carried out on 125 bloodmeals of females caught from outside resting shelters 26% showed positive reaction for man; 70% for cattle and the remaining for other vertebrate hosts. It is not known whether the proportion of females found positive for human blood represents mosquitoes escaping from human habitations or that had actually fed outside on people who were sleeping outside with their cattle nearby during the period of investigation. Salivary glands dissection showed two sporozoite positives among 56 females collected from outside shelters. At the same time the parous rate determined on 54 females collected from outside shelters was 57% giving a probability of daily survival of 0.758 assuming that the gonotrophic cycle of the outside resting population is two days. The outside resting of *A. gambiae* coincided with a large exodus from sprayed houses as demonstrated by window trap observations. Of 364 females of *A. gambiae* collected during September-October by window traps 187 were bloodfed. The survival rate was 88-94% with 301 females collected alive from window traps and held for 24 hours. The species was found to be susceptible to DDT. Indoor collections were performed simultaneously with outdoor searches. The indoor density also markedly increased during September-October with a fed: gravid ratio of 3.5:1 and one of 11 parous females dissected for gland infection was found positive. Haridi suggested that the observed exodus of *A. gambiae* from sprayed houses with high survival may have been partly the result of a natural behaviour pattern of *A. gambiae* species B in this part of Sudan, or a result of the irritant effect of DDT. The high survival rate could also be explained by the ageing of DDT deposits or by a poor quality of spraying and the presence of unsprayable objects suggesting that with partial exophily of *A. gambiae* and irritant effects of DDT, only active deposits of the insecticide would be effective in producing a high mortality. The author concludes that the ability of *A. gambiae* to survive outside is clearly indicated by the high probability of daily survival derived from the parous rate. Despite the relatively low human blood index, the epidemiological significance of the outdoor resting population should not be overlooked and further observations should be conducted aiming at defining the types of ecological conditions favored by outdoor resting populations in different areas in Sudan.

The question of dry season biology of a member of the *A. gambiae* complex (probably species B) and its resurgence in seasonally waterless areas was investigated in Sudan (Omer & Cloudsley-Thompson, 1970). In the valley of the White Nile, the species was found to maintain itself by low-level breeding, as larvae, male mosquitoes and parous females were found throughout the dry season. In contrast in scattered villages of the arid area of Pattasha situated more than 20 km from the Nile Valley regular sampling through the cool dry and hot dry months of the year only nulliparous females were found in inhabited huts, vacant huts, dry wells and animal burrows. The great majority of 213 females collected in 11 dry months during the season 1966 and 1967 had fresh or older bloodmeals but the abdomen was never found fully distended. Their ovaries did not develop beyond Christophers' stage II during the period November-February, stage III in March-April or beyond stage IV in May. Normal development of the ovaries was observed during the favourable season. From these observations, the authors inferred that the female population of *A. gambiae* can adapt itself under severe drought and heat of the arid zone in Sudan, by continuing to feed, but ovarian development is extremely retarded. However, it would be desirable to confirm this by
providing mosquitoes collected during the dry season from the dry areas with bloodmeals and to check the development of the ovaries, (under experimental dry conditions in the laboratory).

The first confirmed record of DDT resistance in A. gambiae came from El Guneid sugar estate Sudan in January 1970 when only 69% mortality was obtained with one hour exposure to 4% DDT. In March 1970, two hours exposure to 4% DDT failed to give complete kill, there being about a 4% survival. The presence of DDT resistance in this population was confirmed by the Ross Institute of Tropical Hygiene, London and its mode of inheritance was studied by Haridi (1972b). This population also has a pronounced resistance to dieldrin. Previously, HCH was sprayed in this locality and it was only in 1969 that it was replaced with DDT. No specific insecticide treatment is given to sugar-cane, but it seems that high selection pressure has been created by pesticides used on cotton plantations prior to sugar-cane cultivation and by pest control currently practised in the surrounding cotton plantations. The area was carefully sprayed with DDT in August 1970 and observations were intensified to determine the operational implications of DDT resistance in this population. As shown in the records four hours exposure to 4% DDT in September 1970 did not give more than 76% mortality. At the same time, trap mortality was about 24% with gravid females forming a large proportion of exit trap collections. The man biting density was as high as 27 per man per night, and the indoor resting density was estimated to be about 60 per man hour. (Unpublished reports to WHO).

2. Anopheles funestus Giles

Next to A. gambiae this is the second important vector of the Ethiopian Zoogeographical Region. It exists in Ethiopia, Somalia and Sudan. Information from these countries on its ecology and behaviour is fragmentary. In Ethiopia, although it is present in most of the areas occupied by A. gambiae, its density is usually much lower except in certain areas where more favourable breeding conditions prevail, O’Connor (1967). From various observations in Ethiopia, Rishikesh (1966) concludes that A. funestus like A. gambiae is highly endophilic and acts as an additional vector. No gland infection could be found in 339 females dissected. It responds to DDT residual house spraying. Limited susceptibility testing recently made in Ethiopia showed that the species is susceptible to DDT, but a low level of resistance to dieldrin was encountered. In Somalia, the seasonal prevalence of A. funestus starts with the advent of the dry season when A. gambiae density declines. Its reaction to DDT house spraying was found favourable.

3. Anopheles pharoensis Theobald

The vector A. pharoensis is widely distributed in the above-mentioned three countries and extends into Egypt. Jolivet, 1959\(^1\) mentions that one specimen was found infected in Ethiopia by Ovassia. Rishikesh (1966) in Ethiopia could not detect any gland infection in 2577 females of this species dissected and he considers that this species is less endophilic than A. gambiae. In Sudan, it was found resting indoors and outdoors. It was often encountered on shaded grasses around houses. No evidence of its being a vector in the above-mentioned countries is available.

In Egypt, the inoculation of this species was first reported by Harber & Rice (1937), who found a sporozoite rate of 0.33% with 1513 specimens dissected during a malaria outbreak. This vector was further studied in 1959-1962 in the southern part of the Nile Delta, by Zahar et al. (1966). Baseline observations showed that it bites man and animal indiscriminately indoors and outdoors. A human blood index of 32.1% was recorded in an area with a

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\(^1\) Unpublished article cited above.
man:animal ratio of 1:7. Partial exophily of this species was demonstrated by using outlet window traps and collection from rice plantations of blood fed females which gave a human blood index of 19.4%. Study of the age grouping of this vector indicated that dry climatic conditions in June do not favour its survival. Longevity markedly increases with the increase of the relative humidity from July to September. After September, a decline in vector output and density occurs with the drying up of rice fields leading to a temporary imbalance in the proportions of nulliparous and parous mosquitoes. Hence, the parous rate hitherto obtained could not be used for assessment.

Even during the favourable period of the transmission season, the longevity of A. pharaohensis is rather short. From studies by the above-mentioned authors in an unsprayed area in 1960-1962 using Polovodova's technique on samples collected by outlet window trap, out of 1980 females dissected 66.7% were nulliparous, 18.6% had one dilatation, 0.15% had two dilatations, 0.55% had three dilatations, 0.05% had four dilatations and the remainder appeared with a follicular sac rendering their age indeterminable. The paucity of aged individuals shows that though A. pharaohensis attains very high biting densities during the favourable season, females of epidemiologically dangerous age are still scarce in the population. This may explain the low infectivity and the low degree of malaria transmission effected by this species. The intensity of transmission may vary from place to place and from year to year depending on the relative humidity and the size of the reservoir of infective cases. Rice cultivation is a very important factor in producing an increase of breeding of A. pharaohensis and in enhancing relative humidity, thus favouring adults' survival.

Prior to 1959 A. pharaohensis was reported to be susceptible to DDT, Zahar (1960). The species was found resistant to both dieldrin and DDT, Zahar & Thymakis (1962) and Zahar, et al. (1965). Resistance appeared also in the A. pharaohensis of unsprayed areas. It was probably related to the extensive use of chlorinated hydrocarbon insecticides for control of cotton pests, A. pharaohensis was found at different stages of the gonotrophic cycle resting temporarily on cotton plants at night. Though selection pressure on larval populations through contamination of breeding places seems to be the more obvious reason, the possibility of enhancing selection in adults making contact with treated plants should not be excluded.

Starting the first cycle in June 1960 a limited scale field trial was implemented in order to evaluate the impact of DDT spraying on malaria transmission when applied at a dose of 2 g techn. DDT/m² once a year over a period of 3 years. Under the influence of insecticidal attack, the overall parasite rate dropped in the first year (1960) to 20% of that of the previous year. This indicated an adequate regression during the first year which, if maintained, would ultimately have resulted in a diminution of malaria to a very low level, MacDonald & Gockel (1964). Parasitological findings indicated that a sufficient degree of vector control was generally maintained in the firs year of attack.

However, there were some operational defects and evidence that the insecticide was starting to wear off in September 1960, when 1.8% of the infants examined became positive. Entomologically the control of vector longevity was satisfactory when the average trap mortality was 70% or more; it became unsatisfactory when the average trap mortality was about 54%. In terms of probability of survival through one day (p), MacDonald (1957), results were adequate so long as this index was kept below 0.5. Taking the data of satisfactory response in 1960 as a basis for assessment, the appropriate critical value for the survival through the extrinsic cycle might be approximately 0.002. Except for the temporary reversal, reflecting operational defects, the overall picture of the year was generally satisfactory.

In the second year (1961), the crude parasite rate showed a much lesser decline indicating a less favourable response. It fell only from 2.37 to 1.87%, the last mentioned level being equal to 16% of the baseline instead of 4% of it as should be expected after two
years of attack, had the initial rate of decrease been maintained. Entomologically, trap mortality was only slightly over half the 70% level required for satisfactory control. In the treated area the vector's probability of survival through one day increased to 0.62 and through the extrinsic cycle to 0.013, i.e. over six times the critical value of 0.002 suggested in the basis of the data of satisfactory response. In the third year of attack (1962) the general parasite rate fell to 4.5% of the original 1959 value, compared with the level of 0.4% expected in that year had satisfactory control been continuously maintained. The slope of the curve implies further low grade transmission in the sprayed area in the third year of attack. The critical level of vector survival through one day was exceeded, as was the probability of survival through the extrinsic cycle. The trap mortality was only 41.8%, again much inferior to the 70% level required for satisfactory control. This unsatisfactory control coincided with deterioration in the susceptibility of *A. pharoensis* to DDT which was determined periodically throughout the observation. Further observations made by Shawarby et al. (1965) confirmed the ineffectiveness of two rounds of DDT spraying, each at 2 g/m², applied to the same trial area in 1963. However, it was not certain whether this was the main factor responsible for continuing transmission, or if outdoor biting and outdoor resting of the vector population have played a role. In addition, the failure to achieve complete interruption of transmission in such a small trial area could not lead to valid conclusions. It was recommended that much larger pilot operations with careful epidemiological assessment should provide the answer as to whether DDT spraying can be the principal weapon of attack in Egypt.

4. *Anopheles multicolor* Cambouliu (considered with *Anopheles sergenti*).

5. *Anopheles sergenti* Theobald

*a. sergenti* is an important vector in the oases and in Fayoum Province in Egypt as well as in Libya. In the eastern part of the Region, it is recorded from Saudi Arabia, Jordan, some pockets in Syria, Iran and Iraq. The eradication of this species was attempted in the Kharga and Dakhla oases of Egypt by an intensive larviciding campaign during 1946-1948, resulting in a considerable drop of the parasite rate from 13.5 to 0.3%. The return of this species to three oases was observed in 1951, Shawarby & Halawani (1957), indicating that the eradication of this indigenous species had not been achieved.

There has been little investigation on the bionomics and behaviour of this species in Libya and Tunisia. It is quite likely that it was the responsible vector of the malaria outbreak of 1964-1965 observed in Ghat and Barakat, at the southern-most borders of Libya. Recently the species was found to be responsible for malaria transmission in the southern part of Tunisia (unpublished report to WHO). However, the role of *A. multicolor* where it exists with *A. sergenti* or alone in these oases remains unknown. *A. multicolor* could not be incriminated in nature, but has been suspected as a vector on epidemiological grounds as it existed alone in some oases having malaria transmission.

Farid (1956) reviewed the situation regarding the breeding habits, ecology, behaviour, infectivity and the relation to malaria of this species in Western Asia. His important observations in Jordan Valley during 1949-1952 showed that despite two cycles of DDT and HCH residual spraying in 1951, malaria transmission occurred in four out of 12 villages. In the northern eastern part of the valley, one round of DDT spraying in April 1952 did not protect the inhabitants. He reported the absence of *A. sergenti* from sprayed premises and their presence in large numbers in outside shelters such as caves and fissures in neighbouring hills. He further emphasized that a malaria outbreak during 1952 was observed at El Gurum where 55.3% overall parasite rate and 3.8% infant parasite rate were recorded. No adult *A. sergenti* were found in sprayed premises but they were abundant in caves in the hills nearby. One sporozoite positive specimen was detected in a sample taken from those outside shelters. Since then, anti-larval measures were introduced to supplement residual house spraying. The insecticide used in oil larviciding was dieldrin until resistance to it was
discovered in *A. sergenti* in the Jordan Valley, Garrett-Jones (1958) when it was replaced by DDT. Singh & Gad (1959) reported some tolerance to DDT in *A. sergenti* larvae which was interpreted as being due to low temperature during the cold season. Davidson (1967) succeeded in raising a self-perpetuating colony of *A. sergenti* from egg batches sent from Faskhha locality in Jordan Valley in May 1967. Tests made with samples from this colony indicated that the species is still resistant to dieldrin but tolerance to DDT was observed. This was probably slightly enhanced tolerance to DDT in the dieldrin resistant strain selected to near homozygosity. DDT house spraying supplemented by larviciding with DDT/diesel oil and later withbouhade gave satisfactory control of *A. sergenti* and consequently no malaria transmission has taken place (reports to WHO).

In Saudi Arabia, larviciding of all potential breeding places of *A. sergenti* using Paris green in suspension (1 kg Paris green, 2 litres kerosene to which Triton X-100 is added at 2% to make 2.5 stock mixture) at a dosage of 0.15 g Paris green/m² did not give satisfactory control during three years' operations in Khaiber oasis. Larvae of *A. sergenti* have not been satisfactorily controlled by this treatment. The output of adults remained high and malaria transmission continued. Zahar (1967).

6. *Anopheles labranchiae Falleroni*

This is a palearctic species having a limited distribution in the North African littoral. It occurred in the north western part of Libya representing the eastern-most limit of its area of distribution in northern Africa. In Tunisia it is the principal malaria vector in a large part of the country, particularly in the northern governorates. Since the implementation of the malaria eradication programme in Tunisia, *A. labranchiae* has succumbed to DDT house spraying as indicated by its virtually complete absence from hand spray captures and bait captures in properly sprayed areas. From the available data of susceptibility tests carried out by Iyengar in 1971 (reports to WHO) about 12% survival was observed with one hour exposure to 4% DDT, but almost complete kill was obtained with two hours exposure to this concentration. Residual spraying together with case detection has succeeded in interrupting malaria transmission in large areas of Tunisia which have been advanced to consolidation phase.

7. *Anopheles claviger Meigen*

*A. claviger* is widely distributed in the Levant. Gramiccia (1956) reviewed its position as a vector where it has been associated with hyperendemic malaria in Jerusalem. It breeds in underground water reservoirs in towns and is there chiefly a domestic species, the adults are found in houses. In rural communities it also breeds in water reservoirs but rests mostly outdoors. In late autumn it becomes domestic and fed females are found indoors. Its feeding habits depend on the availability of hosts near its breeding place but it attacks man readily, mostly outdoors and would also bite in day-time. There are some records of epidemiological evidence indicating that this species was responsible for malaria transmission in areas where it existed alone. No records of its incrimination in the Eastern Mediterranean Region were available except from Cyprus by Stratman-Thomas et al. (1936) quoted by Gramiccia (1956), where sporozoite infection was observed. In October 1970 an outbreak of malaria occurred in a small village on the outskirts of Aleppo, Syria, where 58 indigenous cases of *P. vivax* were detected. *A. claviger* was the only anopheline found in this area and dissection of 20 specimens showed two females with sporozoite infection, Muir and Kellany (1972). Oil larviciding in wells where it bred could bring about control of malaria transmission.

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1 Unpublished report to WHO.
2 Unpublished report to WHO on a visit to Saudi Arabia.
8. **Anopheles hyrcanus** Pallas (under *Anopheles pulcherrimus*)

9. **Anopheles pulcherrimus** Theobald

This species occurs in countries in the north-eastern part of the Eastern Mediterranean Region, such as the eastern part of Saudi Arabia, Syria, Iraq and Afghanistan. In Saudi Arabia and Syria there has been no suspicion of this species being responsible for malaria transmission but in Iraq there was some epidemiological evidence that an outbreak of malaria in a small area was associated with the presence of this species alone (Rishikesh 1972). However, no dissections were made to provide evidence of its incrimination in nature nor have the observations been followed up.

In northern Afghanistan, namely Kunduz area which has been under attack phase for a long time, it is reported that *A. superpictus* could not be found in the last 15 years but *A. pulcherrimus* together with *A. hyrcanus* were recorded as suspect vectors. Since 1966 the number of malaria cases in Kunduz area has steadily increased and attempts were made to detect the responsible vector until gland infections were reported by Badawy (1969) (unpublished reports to WHO) among wild caught *A. pulcherrimus* and *A. hyrcanus*. The majority of positives was observed in delayed dissections of the specimens which were kept under ideal laboratory conditions for varying periods of three to 10 days, but dissections carried out within one day from the date of capture finally demonstrated the natural infection in both species. Various entomological investigations indicated that both species have existed in DDT sprayed areas biting man and animal in high density outdoors, particularly during the season when people slept outdoors. Both species were also encountered resting in natural shelters but *A. pulcherrimus* utilizes also indoor unsprayed shelters such as those missed during spraying. Available data on susceptibility tests showed that *A. pulcherrimus* remained susceptible to DDT whereas *A. hyrcanus* exhibited marked resistance to this insecticide, Badawy (reports to WHO). Both species showed normal susceptibility to dieldrin. This is in contrast to the findings of Peffly (1959a) who reported *A. pulcherrimus* as showing pronounced dieldrin resistance in the Eastern Province of Saudi Arabia. From investigations made by Zahar (1970)\(^1\) in Afghanistan *A. hyrcanus* appeared to play an important role during May and part of June after which *A. pulcherrimus* took over despite DDT spraying. Transmission continued throughout July/August but during the latter month at a slower pace. Results of age grouping dissections carried out on outside resting populations of *A. pulcherrimus* during August 1970 indicated a high parous rate and consequently a high probability of daily survival. Specimens with four to six dilatations were also encountered. This provides evidence that *A. pulcherrimus* could withstand adverse conditions in the outside natural resting shelters. High biting density on man was recorded during the same investigation. In all foci of transmission studied there were obvious operational deficiencies concerning coverage in time and space; thus it was difficult to conclude whether persistence of transmission was totally due to the exophilic tendency behaviour of *A. pulcherrimus* or due to operational defects alone. The identification of *A. hyrcanus* being the type form or a variety of *A. h. pseudopictus* Grassi has not been confirmed.

10. **Anopheles superpictus** Grassi

This important palaeartctic vector is commonly found in association with *A. sergenti* in Jordan and in the north-western part of Saudi Arabia. In these areas, it seems that it has responded to attack measures. It extends further north in the Region where it is found in Syria, Iraq, Iran and in Pakistan, where it was recorded in Baluchistan and south Waziristan. The species was also recorded in Tunisia.

\(^1\) Unpublished report to WHO on visit to Afghanistan.
In Syria, transmission continued in 1965-1966 in Armala area, Idleb Province, in the north-western part of the country where A. superpictus is the principal vector, breeding in hill streams. A household survey of de Zulueta (1966) involving 100 malaria cases and 119 houses of negative persons indicated that sleeping outdoors was rare even during summer months. On the other hand, temporary farm huts built during the period between the two spraying rounds and overlooked during spraying were found sheltering A. superpictus, and consequently transmission persisted. This is in addition to the plastering of houses after DDT spraying had been applied. When total coverage house spraying with DDT was applied, A. superpictus was brought under control and malaria transmission was interrupted.

In Iran A. superpictus is widely distributed except in the coastal area of Shatt el Arab. In the area of the Caspian Sea, however, its distribution is very restricted. The report of the Institute of Public Health Research Teheran, Iran (1965) stated that A. superpictus had a similar pattern of seasonal prevalence as that of A. fluviatilis, their density peaks occurring in the spring and autumn. A. superpictus was found to rest more frequently in stable and less so in inhabited rooms. A. superpictus was also found resting outdoors in pit shelters. Its human blood index was given as 22.4%. Determination of physiological age of the population of A. superpictus by Polovodova's technique showed that 48% were nulliparous and 27% completed one gonotrophic cycle, 6% completed two gonotrophic cycles, 1% completed three gonotrophic cycles, 0.5% completed four gonotrophic cycles and 17.5% had sacs. The proportion of potentially dangerous females in the population of A. superpictus, i.e., females having more than 3 dilatations, was 1.5%. This species together with A. fluviatilis has shown a behaviour refractory to attack measures. Mesghali (1968) summed up the experience with this species that in some parts of Iran, particularly in Kermanshah and Kashaf-rud, Khorrassan, despite the anti-malaria campaign, transmission was not interrupted. It was almost absent from sprayed dwellings but present in caves situated in nearby hills and other natural shelters. Of females taken from caves, 41% had human blood and 0.9% were sporozoite positive. The species was reported to be susceptible to insecticides despite repeated spraying with dieldrin and later with DDT. Likewise, it was found susceptible to malathion.

11. Anopheles fluviatilis James

The vector A. fluviatilis also has a wide distribution in the Region. It exists in the central northern part and in the eastern province of Saudi Arabia, in Iraq and in Iran where it occupies the southern slopes and foothills of the Zagros mountains together with A. stephensi and A. superpictus. It extends its distribution to Pakistan.

As mentioned above, the behaviour of A. fluviatilis was thoroughly studied in Iran. From the report of the Institute of Public Health, Iran (1965) age determination showed that only 1-2.5% of the population of this vector could reach a potentially dangerous age, i.e., over 3 dilatations. The sporozoite rate recorded was 0.98%. According to the same report precipitin tests gave a human blood index of 10%. But this appears to be an underestimation. Like A. superpictus, A. fluviatilis exhibited exophytic behaviour. Mesghali, (1968) summed up the experience with this vector. In Jirfot, southern Iran, when the inhabitants were sleeping indoors, 82.6% of the specimens of A. fluviatilis caught in outside shelters were found to have fed on man indicating that they bite indoors and rest outdoors. In Bandar Abbas area, observations by different techniques indicated that the species feeds indoors and outdoors, rests in houses and in outside shelters. The same author notes that in view of the absence of baseline information on the behaviour of A. fluviatilis and A. superpictus, it is difficult to judge whether natural exophily played a role in the pattern of behaviour encountered after spraying. A. fluviatilis too, is susceptible to DDT, dieldrin and malathion.

1 Unpublished report to WHO.
2 Unpublished article to WHO on "Vector reaction to insecticides and its epidemiological implications".
3 Unpublished article to WHO cited above.
In Saudi Arabia, *A. fluviatilis* which has not as yet been incriminated there as a vector, was considered susceptible to DDT and dieldrin until it was later reported resistant to dieldrin, Peffly (1959).

In Pakistan, *A. fluviatilis* is found in the foothill regions of the mountainous tracts. The role of this species in malaria transmission in this area is not clear although it is known to be a vector in neighbouring countries such as Iran and India. Bloodmeal smears collected from partially sprayed human and animal shelters in the plain areas of Sind gave a human blood index of 5.4%. In the mountainous unsprayed areas, the human blood index was 11.5%, Akiyama, 1968 (unpublished reports to WHO). Malaria in the area dominated by this species, was reported to be hypo-endemic. The classification of abdominal stages of *A. fluviatilis* caught by spray capture indicated its being highly endophilic in the mountainous areas. A sample of 434 females of *A. fluviatilis* were dissected for gland infection, but no positive could be detected. However, further studies are indicated for elucidating the role of this species in malaria transmission in the area of its dominance. In Pakistan the species was found to be susceptible to DDT.

12. *Anopheles d’thali* Patton

This species had not been considered as a vector of malaria in the Region until recently when gland infections were reported.

Rishikesh (1961) found in Somalia one with sporozoite positive glands from among 14 females of this species dissected. It is not understood why none of the *Anopheles gambiae* females dissected at the same time has shown any gland infection. Of the 14 specimens of *A. d’thali*, the ovaries of nine females were dissected and eight were found to be parous. The parasite rate in the human population in the area was around 20%. However, the results of precipitin tests of 11 bloodmeal smears showed no positive reaction to human blood. Observations by baited nets showed that *A. d’thali* mainly bites outdoors. This mosquito may act as a secondary vector particularly during spring transmission when the people sit and sleep outdoors, but it has not been further confirmed.

In Iran, this species was found in association with *A. stephensi*, *A. fluviatilis* and *A. superpictus*. Gland infection was reported by Mesghali in 1967 in *A. d’thali* (unpublished report to WHO) and this was confirmed by Manoochehri et al. (1972). The species was repeatedly found infected during 1963-1967. The sporozoite rates ranged between 1-1.4% and there was a record of three sporozoite positives found among 39 dissected at Arkordan, Borazjan. The human blood index recorded in this species ranged from 1.1 to 38%. High man biting density was recorded. It usually feeds after midnight. Age composition showed a parous rate ranging from 11% to 43%. It was found to rest in both indoor and outdoor shelters. While it is quite susceptible to DDT, it showed some resistance to dieldrin. It was due to its partial exophily that its response to insecticidal house spraying has not been always satisfactory.

13. *Anopheles sacharovi* Favre

The palaeartic species *A. sacharovi* is a main vector in Syria and in the northern region of Iraq, but in Iran it has a more localized distribution in the central, north-western and south-western areas. At the junction of Khabour and Tigris which forms the border area of north-west Iraq, north-east Syria and south-east Turkey, swampy areas provide *A. sacharovi* with suitable breeding places. Outdoor biting of inhabitants sleeping outside during summer months and the suspected outdoor resting of *A. sacharovi* are factors thought to be responsible for persistence of transmission in the ecologically homogenous border area of the three countries, de Zulueta, 1967 (unpublished report to WHO). Larval tests made at Derik, Hassette Province, Syria, in the first week of October 1965 by Cullen (report to WHO), indicated the susceptibility of *A. sacharovi* to DDT.
Reviewing the previous susceptibility records, this vector was subjected to testing in other parts of Syria. Soliman (1961) reported results of susceptibility tests carried out in 1958 in the unsprayed areas of Tel Kanazir, Kamishi, Hassatche Province and Rouge Valley, Aleppo Province, in which some agricultural pest control was applied in 1952, and DDT house spraying was commenced by the malaria eradication programme. Complete mortality was obtained in the two areas with exposures to 4% DDT and 0.4% dieldrin for one hour indicating that the species was susceptible to these insecticides.

In 1960, tests made in June by Keilany (report to WHO) at Haret El Khaleb, Lattaquia Province, showed that A. sacharovi was susceptible to DDT and dieldrin.

In 1963 tests were made in 14-27 October by Thymakis (unpublished report to WHO) at different localities but results were inconclusive, on account of the small numbers tested. However, in some replicates, there was some indication of increased tolerance to DDT as mortality with one hour exposure to 4% was 84.6% (26 exposed) at Ras El Ein, Hassatche Province and 87% (23 exposed) at one locality in Ghab. In the latter prolonged exposure to 4% DDT for two hours gave complete mortality.

In 1967, tests made during 3-9 October and reported by Oddo, de Zulueta and Keilany (unpublished reports to WHO) showed 10.5% mortality with 4% DDT for one hour, 27.5-85% mortality with 4% DDT for two hours and 28.6% with 4% DDT for four hours. During the period of 22 to 29 October one hour exposure to 4% DDT gave 0-19.2% mortality. As for dieldrin, one hour exposure to 0.4% concentration gave 60-78% mortality, 0.8% gave 76.4-96% and 1.6% gave 94-100%.

Ghab area had been under focal spraying since 1964 and it was only in 1967 that the area was put under total coverage spraying. Following a marked increase in malaria transmission A. sacharovi was collected in large densities during October 1967 in both unsprayed and sprayed premises with DDT deposits quite visible in the latter. No other observations were made to ascertain actual room kill in A. sacharovi population. Since the temperature during October 1967 was above 20°C, it was assumed that pre-hibernation adaptation was induced rather by photoperiodic reaction than by temperature bringing about high tolerance to insecticides in A. sacharovi in late October.

Observations were repeated in July/August 1968, just before applying the second round of DDT spraying, Zahar, Onori (1968) (cited in Onori 1972). The average mortality obtained with exposure to 4% DDT for one hour was 19.1% (97 exposed), for two hours 27.1% (294 exposed) and for four hours 62.7% (77 exposed). At the time of susceptibility testing, sprayed surfaces have shown extensive disturbances. A. sacharovi was found in disturbed and apparently sprayed premises in fair density in different stages of the gonotrophic cycle, mostly on unsprayedable surfaces, though a few were collected from sprayed walls. The number of malaria cases was progressively increasing after the first DDT spraying round of 1968. Window trap observations in apparently sprayed and disturbed premises showed that A. sacharovi leaves the house mainly in the empty and gravid states.

The average trap kill recorded in three weeks' observations was not more than 18%. The average biting density per man per night was eight indoors by direct capture and 15 by baited nets. The average house resting density varied from six to 12 A. sacharovi per room. Most of the inhabitants sleep outdoors in summer and A. sacharovi enters houses during the early hours of the morning after feeding outdoors. This together with evidence obtained from daytime capture indicates that A. sacharovi seems to be largely endophilic in that area.

It was difficult to determine to what extent DDT resistance was responsible for persistence of transmission, since large scale disturbance of sprayed surfaces, i.e. replastering and whitewashing sprayed walls, had occurred after the first spraying round. Observations continued after the second DDT spraying round which was applied in the latter half of August-
September 1968. In susceptibility tests during September-October 1968, about 26% mortality was obtained with two hours exposure to 4% DDT and about 46% with 4 hours exposure to the same concentration. These results do not vary much from those obtained prior to the second round of spraying. Spray capture and window trap data indicate that an appreciable proportion of gravid females of A. sacharovi could still be found in sprayed premises. In fact, the latter constituted 59-82% of the trap collection made during a period of one month after the second spraying round. At the same time the average trap kill was about 28%. House resting and biting densities tended to increase after a brief reduction following the application of the second round of spraying. However, both densities did not reach the level recorded before the application of the second round when large numbers of disturbed premises were available for shelter of mosquitoes. The presence of such a density with high survival in window trap catches, however, indicates unsatisfactory response to the DDT spraying of the second round. Supporting epidemiological evidence indicated that transmission persisted in the area after the application of the second round in spite of supplementary mass drug administration. When susceptibility tests to dieldrin were made in August 1968, complete mortality was obtained with one hour exposure to 0.8%, but tests made during September-October showed a few survivors with one hour exposure to 0.8% dieldrin, Chang and Keilany (reports to WHO). It was thought that this small survival could be attributed to pre-hibernation tolerance. On the basis of the above investigations it was decided to replace DDT with dieldrin and commencing in 1969 the areas of DDT resistance received two spraying rounds of dieldrin per annum.

The density of A. sacharovi was drastically reduced as indicated by different methods of capture following dieldrin spraying and a few tests made with 0.8% concentration on small samples that could be collected showed either complete mortality or an occasional survivor. With a small batch of A. sacharovi tested in September 1971 there was for the first time 25% survival with one hour exposure to 0.8% dieldrin. The susceptibility level was thoroughly checked by Keilany (reports to WHO) during July-August 1972 and the results demonstrated without doubt pronounced dieldrin resistance in A. sacharovi. The mortality with one hour exposure to 4% dieldrin was below 10% and there was little difference between the mortalities obtained with the different concentrations of 0.8% to 4% dieldrin.

14. Anopheles stephensi Liston

The oriental vector A. stephensi occupies a fairly large territory in the northern and eastern part of the Region.

A. stephensi mysorensis was identified in the Eastern Province of Saudi Arabia, Peffly (1959a) and in southern Iran, Mofidi (1962) cited in Chang and Ungureanu (1965).

A. stephensi in Iran, Iraq and Saudi Arabia is resistant to DDT and dieldrin. The status of resistance in this vector and its operational significance were reviewed by Chang and Ungureanu, (1965). As DDT residual house spraying could still curtail the severe malaria epidemic which occurred in Iraq and Iran in 1962-1963, DDT residual spraying was re-instituted in the A. stephensi area of southern Iran and Iraq in combination with other measures such as surveillance and larviciding operations, in an effort to interrupt malaria transmission. Periodic checking of the susceptibility levels of A. stephensi was pursued and routine estimation of house resting density by spray capture continued.

Results from southern Iraq have been reviewed by de Zulueta et al. (1967). Susceptibility tests carried out during 1965 and early in 1966 indicated no further increase of the resistance level of A. stephensi in the above-mentioned area. It was only in November 1966 when an extremely low kill was recorded. The average mortality obtained with exposure to 4% DDT for one hour was between 10 and 10.2% in Fao and Shatt el Arab areas respectively of southern Iraq. Even prolonged exposure to 4% DDT for four hours in Fao Mamlaha did not give more than 2.5% mortality. This locality received three rounds of DDT spraying with excellent coverage.
The great increase of the resistance level coincided with a marked increase of *A. stephensi* densities in Basrah Liwa. The room density during August, September and November 1966 was about 10-29 times of that recorded during the corresponding months in 1965. According to the above-mentioned authors the species was observed to spread beyond its normal limits of distribution in the country and was found as far away as Kirkuk Liwa in the northern region of Iraq.

The possibility that several forms of *A. stephensi* existed in southern Iraq and Iran having different potentiality for malaria transmission was considered by the above-mentioned authors. An example was given from Fao area in southern Iraq where transmission persisted since the re-institution of DDT house spraying in 1964, as compared with other areas where the species existed but transmission has been interrupted or has continued at a very low pace. As Fao Mamlaha had yielded the highest number of indigenous malaria cases and its breeding places have a high salinity, it was thought that a saltwater form of *A. stephensi* with higher infectivity than that of the freshwater breeder existed. From laboratory investigations carried out at the Ross Institute of Tropical Hygiene, London, using different strains of *A. stephensi*, it was demonstrated that there was no evidence of hybrid sterility among the five populations originating from India (Delhi), Iraq (Fao Mamlaha, Gezira and Baghdad) and Iran (Kazeroun) respectively. It was also suspected that more than one type of DDT resistance may exist in *A. stephensi* populations in southern Iraq. Crosses made at the Ross Institute indicated that resistance in colonies from Gezira and Fao Mamlaha in Iraq is genetically identical. Crosses between the Fao Mamlaha strain and a susceptible strain from Delhi indicated that the DDT resistance in *A. stephensi* is near-dominant and that a single genetic factor is involved. From selection studies, the above-mentioned authors assumed that the changes in the pattern of resistance of this species to DDT in southern Iraq might be explained by the existence of genes ancillary to the oligogene common to all populations studied. Absolute homozygosity for all genes does not appear to have been reached as indicated by the increased mortalities recorded in the same areas of southern Iraq in 1967 which continued to be sprayed with DDT.

Assessment of the malaria situation in southern Iraq indicated an almost equal parasite incidence throughout the three years, during which period the house-resting density of *A. stephensi* was generally low with the exception of 1966. This may illustrate that resting density indices alone do not necessarily reflect the epidemiological significance of a vector population. Checking such indices by simultaneous observations on vector/man contact and trap mortality together with age-grouping of the vector population would have been pertinent.

DDT spraying continued during 1968 with no appreciable reduction of malaria transmission in southern Iraq. In fact in that year a malaria outbreak occurred in a group of villages in Basrah Liwa. An entomological investigation was carried out during October 1968 in villages where indigenous cases were recently recorded (Zahar, 1969). The spraying coverage in the area was estimated during the investigation to be about 94%. In sprayed rooms, *A. stephensi* was captured from unsprayed surfaces but some were found resting on sprayed surfaces. The average densities of *A. stephensi* were 5.2 per sprayed room and 6.7 per unsprayed room. The susceptibility tests showed 6.5% mortality with one hour exposure to 4% DDT and 26.5% mortality with four hours exposure with specimens collected from unsprayed shelters while 17.7% was recorded with four hours of 4% DDT with specimens collected from sprayed premises. Two nights of window trap collections showed that the maximum exodus of *A. stephensi* from sprayed houses was two to three hours after sunset. Gravid females constituted a large proportion of trap collections indicating that the mosquitoes were completing their gonotrophic cycle in the sprayed premises. The average density per trap per night was 10 *A. stephensi*. The mortality rate after 24 hours holding period obtained with 96 unfed and 125 fed females was 30% and 14% respectively. At the same time the parous rate

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1 Unpublished report to WHO on visits to Iraq.
recorded on samples collected from sprayed premises was 53%. Assuming that the gonotrophic cycle was two days the probability of daily survival was about 0.726. During dissections a number of females were found to have 3–6 dilatations confirming that A. stephensi enjoyed high survival within sprayed premises. For comparison a parous rate of 60% giving a value of probability of daily survival of 0.775 was recorded in an unsprayed urban area in the central region where transmission had recurred. This figure is very close to that estimated for the DDT sprayed area.

In view of the above results it was decided to replace DDT with malathion in Barah Liwa. Observations made throughout 1969/1972 indicated that a good response was obtained under malathion spraying and A. stephensi has become very scarce except in situations where refusals or operational defects occurred. The supporting epidemiological evidence indicated that transmission has almost been interrupted (unpublished reports to WHO). In 1968 a small area comprising of two villages was sprayed with propoxur (OMS-33). Indigenous cases started to appear shortly after the second spraying round, giving the impression that transmission did continue despite the fact that A. stephensi could not be found by different techniques namely daytime capture, bait capture and larval searches. Observations throughout 1969 confirmed that these cases were relapses which possibly had not received radical treatment previously and that transmission in this area was in fact interrupted under propoxur spraying.

Reference should be made to the feeding habits of A. stephensi as determined by Chang 1967 (unpublished report to WHO), who sampled 547 bloodmeal smears for precipitin tests taken from sprayed bedrooms and unsprayed vacant shelters in the sprayed area in southern Iraq. The proportion of smears which gave positive reaction to man was 5.1% (46 smears) at Hakra village where the ratio of man:cow in the compound of collection was 3.5:1; 1.9% (406 smears), at Shatt el Arab where the ratio of man:cow in the compound was 3.1:1; but 53.7% (43 smears) was recorded from another compound in the latter village where a ratio of man:cow was 4.0:0. The nearest cattle to this compound was at a distance of 100 metres. Chang concluded that A. stephensi is definitely a zoophilic vector, and that the human blood index varies considerably according to the availability of animal host, and in consequence transmission intensity varies. Data on direct measurement of the degree of biting man and animal in this area is fragmentary. With an endophilic species, it may be possible that even with the presence of one or two cows in a yard of a compound, entry of mosquitoes to human habitation for sheltering after having fed on animals outside, would give rise to distorted human blood indices.

In Iran, data collected by Kazeroun Research Station as quoted in the report of the Institute of Public Health Research, Teheran, (1963), prior to spraying in the area of insecticide evaluation, showed that the average density of A. stephensi per room was 200 and that from June to October the density was higher in human habitations than in stables. It was observed resting on clothes and straw material and occasionally on walls. From October to December mosquitos were often found in stables. They were occasionally collected from pit shelters. However, A. stephensi is known to be largely endophilic. In longevity studies 4.4% of A. stephensi dissected were found to have at least three dilatations and therefore to be in a potentially dangerous age. The sporozoite rate recorded was 0.51%. Precipitin tests showed a human blood index of 21%. Using two humans and one animal in a magoon trap, A. stephensi showed maximum human blood preference of 47% and a minimum of 5%.

Continuous evaluation of DDT spraying showed that resistance of A. stephensi to DDT was increasing, and that transmission persisted in southern Iran as in southern Iraq. Therefore, malathion was first tried on village scale.

Subsequently in 1967, it was decided to spray in the littoral and plain areas DDT in one round only in the spring and malathion in a second round in 1967. According to the report of the Institute of Public Health Research, Teheran (1967) A. stephensi density in the coastal area, despite DDT spraying in the spring, has shown a steady increase from June
until September. Persistence of transmission was observed in a village in the coastal area, where the density of *A. stephensi* was 15.2 per room and the proportion of dangerous females had reached a maximum in September 1967. Dissection of 136 *A. stephensi* females gave a sporozoite rate of 1.47%. At the same time 10 cases of *Plasmodium vivax* infections were detected in the village. In October, after applying malathion, a marked reduction in house-resting density was observed. This was demonstrated by spray capture surveys in six indicator villages where the average density of *A. stephensi* was 6.3 per room in July, 4.3 in August, 7.5 in September and 0.1 in October. However, since seasonal changes intervened, it was difficult to draw a firm conclusion on the success of malathion which was applied during September-October 1967.

In 1968 the regimen of DDT spring and malathion autumn spraying rounds was applied but the latter spraying was started to start in mid-August.

It should be recalled that throughout 1965-1968 the susceptibility tests of *A. stephensi* showed a steady deterioration, falling in 1968 to a mortality of 15.7% with one hour exposure to 4% DDT. A high parous rate was recorded during August and September 1967 (68.8% and 79.3% respectively) with a probability of daily survival of 0.63 and 0.89 respectively before malathion was applied in October 1967. At the same time the mortality in window trap collections was not more than 7%. The parous rates of 55% and 56% recorded in July and August 1968 respectively during the post-operational period of DDT were relatively lower than before. Parasitologically there was a slowly rising trend but of lesser incidence than in the previous years when DDT spraying only was applied in two rounds. The density of vectors in houses was generally low as indicated from spray catches and no mosquitos could be captured in night catches or by window traps. It was concluded that under the regimen of two annual DDT spraying rounds there was always a marked building up of the density of *A. stephensi* which was combined with increasing longevity leading to persistence of transmission at a fairly high rate. Under the regimen of DDT and malathion there was a definite shortening in the period of vector activity and the height of its density resulting in a much lower rate of transmission. Malathion reduced the *A. stephensi* population drastically and it was suggested that in view of the stepping up of the level of DDT resistance it would be better to totally replace DDT with malathion, Zahar (1969). According to recent records from Iraq and Iran *A. stephensi* remains susceptible to malathion in areas where the spraying with this insecticide is in progress.

It is worth referring to observations made by Quarishi et al. (1966) in Iran on the range of flight by releasing $^{22}P$ labelled *A. stephensi*. Since the number of recaptures was very small and variations were numerous, catches could be taken only as indicating a rough trend. The number of mosquitos recaptured markedly fell at 3-5 km. The authors believe that *A. stephensi* had a considerably longer range of flight than 2 km. Their observations also showed that males and females of this species were able to fly 1.8 km overnight. One female was caught in a village at 2.8 km from the point of release within 16 hours after release. These results are important in the context of border areas. For example, the breadth of the Shatt el Arab river between southern Iran and Iraq ranges between 600 m and 3000 m. Therefore, the possibility of an exchange of population of *A. stephensi* between the two riverbanks with the genetical and epidemiological implications, calls for closely and continuously coordinated efforts.

In Pakistan, *A. stephensi* occurs in variable densities in association with *A. culicifacies*. In the urban area of Karachi, Husain & Talibi (1956) reported monthly dissections carried out from 1947 to 1951, during which a total of 23223 *A. stephensi* were dissected for gland infection and 9617 of these also examined for gut infection, in both cases with negative

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1 Unpublished report to WHO on visits to Iran.
results. Afridi et al. (1958) showed that A. stephensi mysorensis occurs in Karachi, Sukkur and Hyderabad Zones, though the type form was either not found or, if present, occurred in such small numbers that it could not be detected.

Rahman and Muttalib (1967), investigating the malaria situation in Karachi city reported a spleen rate up to 34.3% and a parasite rate of 15.5%, and that A. stephensi and A. subpictus were the only anophelines encountered either as adults or larvae in the different parts of the city surveyed. The authors found one female A. stephensi with sporozoites among 204 dissected during July-August 1966 in Karachi city. Further dissections were made on 505 A. stephensi and 205 A. subpictus collected from the city with six gland infections (1.18%) in A. stephensi and none in A. subpictus. In April 1967, 0.3% gland infection was recorded on 328 dissections of A. stephensi.

Susceptibility tests carried out in Karachi city in 1967-1968 indicated resistance of this vector to DDT but at much lower level than that noted in Iran and Iraq. The mortality recorded with exposure to 4% DDT for one hour ranged from 32.5 to 80% and for two hours from 76 to 92%.

A. stephensi in Karachi city was found in a wide variety of breeding places including polluted and brackish waters, and a larviciding programme was organized aiming at eradication of malaria from urban areas. Precipitin tests run on 45 bloodmeal smears of A. stephensi taken from houses in October 1966, showed that only two gave positive reaction to man, (4.4%) and the remaining smears gave positive reaction to various domestic animals mainly bovid and horse. The man:animal ratio in the locality of collection was 100:3, with animals 3 m from the bedrooms. These smears were taken from malaria patients' houses, where average density of A. stephensi was 20.5 per room and gland infection was 0.9% as recorded on 110 females dissected. In May 1967, when a larger sample of 85 smears was collected also from human habitations at a locality having a man:animal ratio of 100:1, only 10.6% gave positive reaction to man, which is not significantly different from the first result. In April 1968, from a batch of 236 blood smears collected from human habitations in three localities in Karachi, only seven smears (about 3%) gave positive reaction for man; the remaining smears gave positive reaction for the usual domestic animals, namely bovid, horse, sheep/goat and dog. The parasite rate in the human population in the localities of bloodmeal smears ranged from 19-29%.

The very low human blood index recorded requires further investigation. Observations showed that an appreciable number of domestic animals exist in the city. Cattle are either sent out to the outskirts far from houses for grazing, or are locked indoors during daytime. The density of the vector may present another factor influencing sampling of bloodmeal smears. The density of A. stephensi at the time of collection of the last batch of smears from Karachi was 15.6-35.3 per room. No information is available as to the number of rooms from which bloodmeal smears were collected. It is likely that collectors were attracted by a high density existing in one or two rooms to obtain a large sample of bloodmeal smears. As mentioned earlier, with an endophilic species, the presence of a few domestic animals at night in close proximity to bedrooms, may give rise to an exaggerated proportion of animal-fed mosquitoes.

Information on A. stephensi in rural areas in Pakistan is given under the review of Anopheles culicifacies below.

A species found at Ras Ghareb, Red Sea Area, Egypt, was identified as A. stephensi by Gad (1967). The identification was checked by Dr P. F. Mattingly (British Museum – Natural History) who found it resembling A. dancalicus Corradetti, although he was inclined to consider it as being slightly aberrant A. stephensi. The breeding places and the ecological conditions in the locality of the species were described by this author. Further information refers to its larvae being susceptible to DDT, dieldrin, lindane and malathion, (Gad & Kamel...
1967). There has been no evidence of malaria transmission occurring in the area where the species was found. However, control of breeding places by oil larviciding was introduced A. stephensi was also recorded in the northern section of United Arab Emirates, (vide A. culicifacies).

15. Anopheles culicifacies Giles

The oriental species A. culicifacies is the principal vector in Pakistan and is widely distributed in that country. It has been connected with the unstable type of malaria. Throughout the rural areas of central and southern Pakistan it is commonly associated with A. stephensi. Pre-spraying observations showed that the two species are found throughout the year. A. culicifacies appears in high density in April, declining in May–June but increasing again from July–August to reach a peak in September–October. A. stephensi density declines in July but again increases in August, reaching a peak in September. The lowest densities of the two vectors are usually encountered during December–February. With the commencement of the malaria eradication programme in 1961, DDT residual house spraying was successful in drastically affecting the densities of both vectors and consequently leading to satisfactory epidemiological results, on the basis of which many zones were shifted into consolidation phase. The two species being endophilic were found to be absent or scarce from properly sprayed houses after the application of DDT. However, high densities of both species were encountered whenever operational defects occurred necessitating continuation of DDT spraying in certain sectors (unpublished reports to WHO). Records of susceptibility tests made during 1962 indicated that A. culicifacies was susceptible to DDT. However, resistance started to appear from 1964 onwards in both species in different zones (reports to WHO). Throughout 1967–1970 more records of DDT resistance in both A. culicifacies and A. stephensi were obtained, reaching a high level in most zones although the sample size in the tests was generally around 50 to 60 mosquitoes, not allowing inferences to be made on the resistance level in the general mosquito population (unpublished reports to WHO). No special investigations were carried out to determine the practical implication of this resistance. However, the epidemiological situation has been studied in areas recently stricken with a flare-up of malaria transmission and this was correlated with a high level of DDT resistance in both vectors. On the basis of this, a trial has been made using gamma-HCH for residual house spraying, the results of which are not yet available (unpublished reports to WHO).

In 1968 a survey was carried out in the northern part of the United Arab Emirates (previously known as the Northern Trucial States) Zahar (1969).\(^1\) A. culicifacies s.l.\(^2\) in association with A. stephensi was found in high densities, connected with a high endemicity of malaria (with crude parasite rates between 15 and 49%). The parasite formula showed 68.5% Plasmodium falciparum, 22.4% P. vivax and 9.1% P. malariae. A. culicifacies and A. stephensi were found breeding in wells and cement basins used for water storage in the rural areas. Wells are the only source of water in this area.

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1 Unpublished report to WHO on a malaria survey in the Northern Trucial States.

2 The identification of this species was checked by Dr M. T. Gillies who indicated that the present form appears to be intermediate between the nominate subspecies and the subspecies adenensis but, for the time being, suggested that it should be referred to simply as A. culicifacies s.l.
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RESUME

L'auteur passe en revue la documentation disponible sur l'écologie de 15 vecteurs du paludisme de la Région OMS de la Méditerranée orientale.

Les renseignements présentés se rapportent surtout à la période écoulée depuis 1956, date du lancement du programme de lutte ou d'éradication dans cette Région. Les données concernant l'étude épidémiologique de la situation du paludisme et l'évaluation des mesures d'attaque du point de vue entomologique sont tirées des travaux publiés à ce sujet ou de rapports non publiés adressés à l'OMS. Des indications sur le degré de sensibilité aux insecticides des vecteurs du paludisme, et sur le comportement et la mortalité des populations de vecteurs ayant fait l'objet de mesures d'attaque, sont également fournies dans cette analyse qui renseigne en outre sur l'indice d'anthropophilie, la préférence trophique et la longévité des vecteurs. Les informations relatives à chaque espèce sont plus ou moins complètes, selon l'importance des recherches entomologiques effectuées dans les diverses zones, mais l'article a le mérite de faire apparaître les lacunes de nos connaissances sur l'écologie des vecteurs, ce qui devrait inciter les chercheurs à poursuivre leurs observations ou à entreprendre de nouvelles investigations.
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The purpose of the WHO/MAL series of documents is threefold:

(a) to acquaint WHO staff, national institutes and individual research or public health workers with the changing trends of malaria research and the progress of malaria eradication by means of summaries of some relevant problems;

(b) to distribute to the groups mentioned above those field reports and other communications which are of particular interest but which would not normally be printed in any WHO publications;

(c) to make available to interested readers some papers which will eventually appear in print but which, on account of their immediate interest or importance, deserve to be known without undue delay.

It should be noted that the summaries of unpublished work often represent preliminary reports of investigations and therefore such findings are subject to possible revision at a later date.

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