# *ANOPHELES* MOSQUITOES AND IMPORTED MALARIA IN LIBYA

C.D. RAMSDALE

*Varndean Lodge, London Road, Brighton BN1 6YA Sussex, England*

ABSTRACT. *Anopheles multicolor* Cambouliu, *An. sergentii* Theobald and, in a circumscribed coastal area, *An. labranchiae* Falleroni are considered to have been vectors of malaria in Libya where the incidence of imported malaria has increased. Libyan records of the Afrotropical vector *An. gambiae* Giles *sensu lato* are considered erroneus. However, two factors increase the risk of invasion from the south by *An. gambiae* or *An. arabiensis* Patton. These factors are the bridges across the desert formed by improved roads and local air traffic, plus the increasing receptivity to both imported malaria and its vectors in many parts of Libya where subterranean sources of water are being used for development and irrigation. This applies especially in the Fezzan, historically the most malarious part of Libya.

## INTRODUCTION

Libya (Libyan Arab Jamahiriya) is an extremely arid North African country extending southwards from the Mediterranean into the Sahara (Fig. 1). Annual precipitation reaches 350 mm along the coast and almost 500 mm on the Jebel Akhtar in the northeast; elsewhere it is spasmodic and rarely reaches 25 mm. The Jebel Akhtar massif has vegetation cover but, in general, the desert extends to the sea. Cultivation is confined to a discontinuous coastal strip and to some oases, notably those of the Fezzan.

Many Libyan oases, like those in other parts of the Sahara, have a history of occasional outbreaks of malaria involving *Plasmodium vivax* Grassi and Feletti and *P. falciparum* Welch. The latter species of malaria parasite has been eradicated from the Mediterranean basin but still predominates in Africa south of the Sahara. Due to specific immunity of the people (Luzzato 1979), *P. vivax* is absent from West Africa. It has been eradicated from Europe since 1975 (Bruce-Chwatt and de Zulueta 1980) and almost eliminated from the Mediterranean basin, though transmission persists in some Middle Eastern and North African countries.

The present comparative freedom from autochthonous malaria enjoyed by most countries bordering the Mediterranean has not been accompanied by reduced incidence of malaria imported from outside the region. In Libya, a continuing influx of foreign workers, many from highly malarious parts of the world, ensures the maintenance of a parasite reservoir probably larger than at any time in the past. Moreover, improved air and road communications increasingly facilitate population movement within, as well as into the country. It follows that up-to-date information on prevalence of anopheline mosquitoes, some of which are the vectors of human malaria parasites in Libya, continues to be of relevance to public health. This review stems from advisory visits involving field surveys of Libyan anophelines for malaria control purposes.

## DISCUSSION

Despite the generally low endemicity of malaria under historical conditions in Libya, malariological records were compiled since the early 1900's under successive Italian, British and Libyan administrations, especially in the Mediterranean littoral, giving fragmentary information on anopheline prevalence. Brighenti (1930) and La Face (1937) reviewed information gathered principally by Franchini (1927, 1928), Longo (1930), La Monaco Croce (1931), Seguy (1932), Ghidini (1934), Ragazzi (1933), and Zavattari (1934) during the Italian occupation when a total of eight anopheline species were recorded. The review of Goodwin (1961) included the findings of Lodato (1935) and Vermeil (1953), as well as unpublished data collected by the British military and civil authorities and the pre-eradication surveys of the Libyan national malaria programme. Table 1 lists fourteen species of *Anopheles* recorded in the three administrative regions of Libya up to 1960 (Goodwin 1961).

Citing Brighenti (1930) and La Face (1937), Goodwin (1961) erroneously listed two further species, *Anopheles claviger* Meigen and *An. pharoensis* Theobald. These authors merely discussed the possible presence of *An. claviger* and La Face's reference to *An. pharoensis* concerned East Africa, not Libya. La Face also speculated as to which members of the *An. maculipennis* Meigen group were present in Tripolitania.

Except for *An. rufipes broussesi* Edwards, locally abundant in the Fezzan, only *An. multicolor* Cambouliu and *An. sergentii* Theobald have been detected in more recent surveys, which have been concerned mainly, but not exclusively, with the Fezzan (Goodwin and Paltrinier 1959, Kadiki and Ashref 1972, Zahar 1966) and these two species are widely distributed in Libya.

Bearing in mind the uniform severity of the arid climate, the apparent absence of desert species such as *An. dthali* Patton and *An. rhodesiensis rupicolus* Lewis is surprising

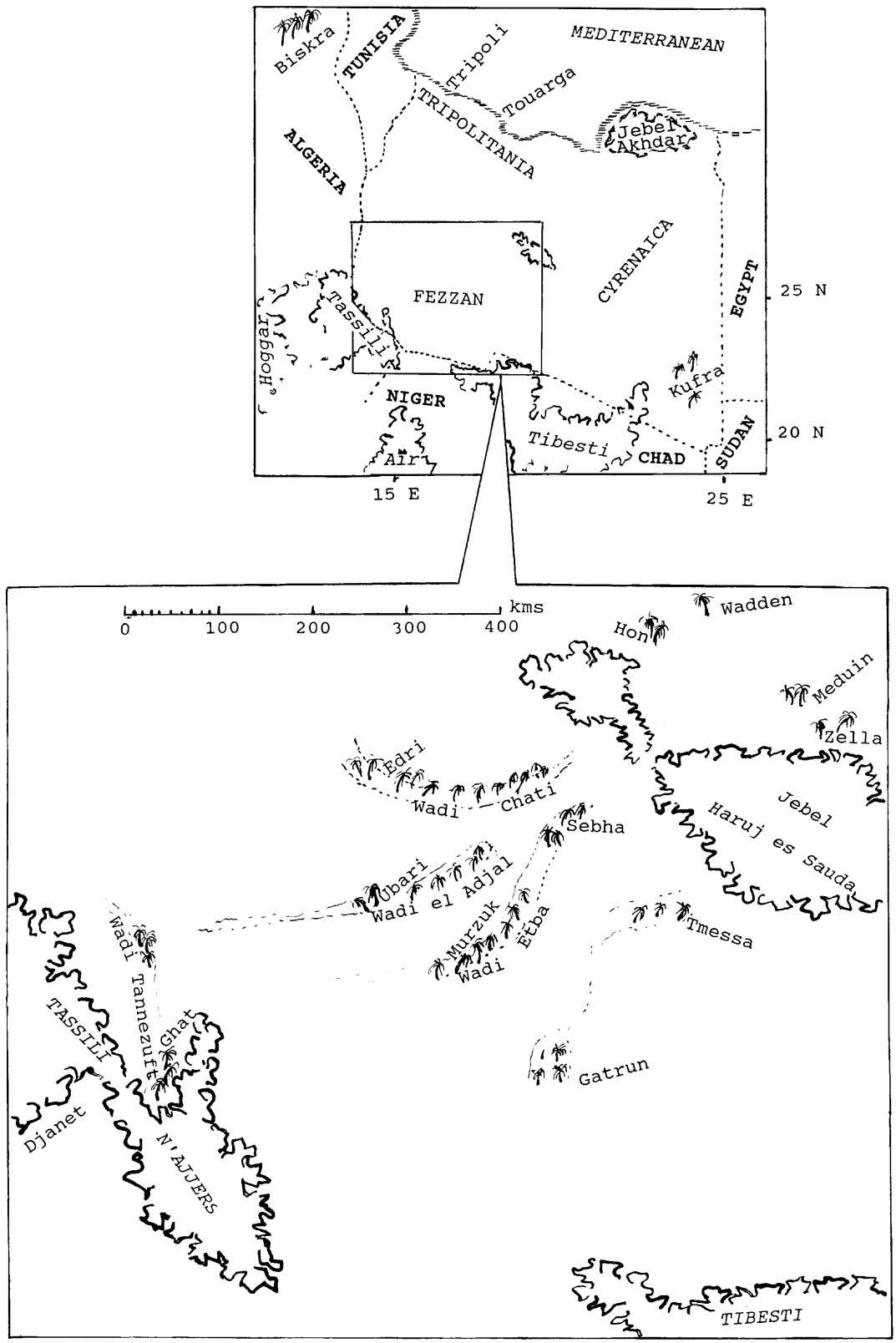


Fig. 1. Sketch map, with enlarged representation of Fezzan.

**Table 1.** Anophelines recorded from the different regions of Libya.

| | Regions | | | |
|---|---|---|---|---|
| | Tripolitanian | Cyrenaican | | Fezzan |
| Subgenus | | littoral | Kufra | |
| *Anopheles* | | | | |
| *algeriensis* | + | - | - | - |
| *coustani* group | + | - | - | - |
| *hyrcanus* | + | + | - | - |
| *maculipennis s.l.* | + | - | - | - |
| *marteri* | - | + | - | - |
| *sacharovi* | + | - | - | - |
| *tenebrosus* | + | - | - | - |
| *ziemanni* | + | - | - | - |
| *Cellia* | | | | |
| *cinereus* | - | + | - | + |
| *gambiae s.l.* | - | - | - | + |
| *multicolor* | + | + | + | + |
| *rufipes broussesi* | - | - | - | + |
| *sergentii* | + | + | - | + |
| *superpictus* | + | + | - | + |

since both are endemic to the adjacent Algerian oases of the Tassili N'Ajjer (Ramsdale and de Zulueta 1983). Moreover, the Libyan records, especially those from the Fezzan, of non-desert species not found in neighboring territories are remarkable and deserve reexamination.

Following a report by Zavattari (1934) of mosquito larvae, including those of *An. claviger*, *An. maculipennis s.l.* and *An. superpictus* Grassi, in water containers carried on caiques and sponge fishing boats plying from Aegean ports, La Face (1937) discussed possibilities of passive introduction into Cyrenaica of these and other species. Frequent landings of military aircraft from East and West African or Middle Eastern staging posts during the 1939-45 war and the steady expansion of civil airways and other international flights added easier means by which exotic mosquitoes might be imported (Smith and Carter 1984). Occasional records do not, however, prove establishment of introduced species, which depends on ability to exploit local, exacting conditions.

The following consideration of anopheline ecological requirements may help in deciding which of the species recorded from Libya may be regarded as indigenous.

***Anopheles algeriensis* Theobald.** This western Palaearctic species is common in coastal regions of the Maghreb (Morocco, Algeria and Tunisia), where larvae are found in brackish ponds and marshes (Senevet and Andarelli 1956). In Algeria it occurs in overgrown, brackish water collections in the Biskra group of oases (Ramsdale and de Zulueta 1983), as well as to the north of the Atlas Mountains. Similar larval sites occur in some coastal localities in Libya, but the only records of *An. algeriensis* are from Tripolitania (Figure 1).

***Anopheles claviger* Meigen.** This very widespread Palaearctic species requires cool water for larval development and has only been able to extend its range into the Middle East by exploiting water in underground cisterns, a niche which does not exist in Libya. A sibling species, *An. petragnani* del Vecchio, able to tolerate slightly higher water temperatures (Coluzzi 1962), is confined to the western Mediterranean where it occurs sympatrically with *An. claviger* (Coluzzi et al. 1965). The nearest North African records of these species are from northern Tunisia and Algeria where interjacent Atlas and coastal areas provide suitable larval habitats.

***Anopheles marteri* Senevet and Prunelle.** The specialized, cool, mountain stream habitat of *An. marteri* does not occur in Libya and the single record cannot indicate the presence of an established population of this species. Of two morphologically separable subspecies, *An. marteri sogdianus* Keshish'yan appears to be limited to southwestern Asia and the eastern Mediterranean, though there is a record from Sardinia (Shahgudian 1956). A future finding of this form in Libya would suggest importation from the Aegean or Middle East rather than from the Maghreb where only the type form is found.

***Anopheles maculipennis* Meigen group.** Ecological constraints in Libya, such as the brackishness of most coastal larval habitats and the hot, arid climate would exclude members of the *An. maculipennis* group except *An. labranchiae* and *An. sacharovi* Favre, the presence of

which was suggested by La Face (1937). The only actual record of *An. sacharovi* was based on the identification of two first-instar larvae (Goodwin and Paltrinier 1959) and can be discounted in view of the unreliable diagnostic value of larval characters. Other records are of adult specimens and attributable to *An. labranchiae*, since *An. sacharovi* can be distinguished on characters of adult external morphology. In neighboring countries, no members of the *An. maculipennis* group occur in Egypt and *An. labranchiae* is the only one present in Algeria and Tunisia (Senevet and Andarelli 1956) where it is the principal vector of malaria parasites.

***Anopheles coustani* Laveran group.** Early reports of *An. coustani* from Tripolitania (La Face 1937) are supported by specimens of *An. ziemanni* Grünberg from Touarga in the British Museum (Natural History). Two species of the *An. coustani* group, *An. ziemanni* and *An. tenebrosus* Dönitz have been recorded subsequently at Touarga (Goodwin 1961). There are records of the former from Morocco and Tunisia, while the range of *An. tenebrosus* includes the Arabian Peninsula, northeastern Egypt and the Middle East (Gillies and de Meillon 1968). Occasional maritime introduction of either species into the coastal Touarga area could occur and one or both may be established or endemic.

***Anopheles hyrcanus* Patton.** Three records of *An. hyrcanus* from coastal areas of Libya (Goodwin 1961) include a report of "var. *pseudopictus* Grassi" from Cyrenaica (Franchini 1927). In contrast to southeast Asia (see Reid 1968), this widespread group of species has been inadequately studied in the Palaearctic where several forms of uncertain taxonomic status have been described, including *An. hyrcanus* Pallas from Tripolitania.

The paucity of records seems to indicate that *An. hyrcanus* is not established in Libya or elsewhere in North Africa.

***Anopheles cinereus* Theobald and *An. superpictus* Grassi.** *Anopheles superpictus* larvae develop in collections of clear, fresh water often devoid of vegetation and subject to considerable solar heating, in stony backwaters in streams or in residual pools in drying seepages or stream beds (Leeson et al. 1950). This niche is filled by *An. cinereus*, formerly treated as *An. hispaniola* Theobald (Dahl and White 1978), in the Maghreb since *An. superpictus* is not indigenous to North Africa. Coastal records can be explained in terms of occasional maritime introduction. Importation into the Fezzan, from which there are three old records of *An. superpictus*, would require transportation across more than 1000km of desert. However, erroneous identifications might offer another explanation. The female maxillary palps of *An. superpictus* and *An. cinereus* are subject to considerable variation with three- or four-banded or light- or dark-tipped forms occurring in both species. Further, aberrant larvae of *An. cinereus*, in which one of the long mesopleural setae appears simple until viewed under a high (400x) magnification, are common in the Sahara (Holstein et al. 1970), which compounds the possibility of misidentification. It is possible that the inland records, at least of *An. superpictus*, may refer to *An. cinereus* which is common in the contiguous oases of southern Algeria (Ramsdale and de Zulueta 1983) and elsewhere in the Western Desert (Guy 1959, Senevet and Andarelli 1956).

***Anopheles gambiae* Giles complex.** During the course of malaria control operations in the Fezzan, Lodato (1935) reported that *An. gambiae* (as *An. costalis* Giles) was the only anopheline present in a wide area including the Wadis Chati and El Adjal. Contemporary workers recorded *An. cinereus* (as *An. hispaniola), An. multicolor, An. sergentii* and *An. superpictus* (Ghidini 1934, La Monaco Croce 1931), but not *An. gambiae*. Since then the ubiquitous presence of *An. multicolor* and *An. sergentii* has been repeatedly confirmed, but not a single specimen of *An. gambiae* has been encountered.[1] Records of specimens of *An. gambiae* amongst those of other species would have been difficult to challenge, but the report that this was the only species present indicates that errors of identification were made. The distribution of the *An. gambiae* complex extends along the southern limits of the Sahara (Gillies and de Meillon 1968). The most northerly records of *An. arabiensis* Patton and *An. gambiae* are from 17° 00'N near Agades, Niger (Stafford Smith 1981) and 17° 35'N in the area of Boutilimit, Mauretania (Coz 1973) respectively, but an unidentified population of *An. gambiae s.l.* was found at 22° 22'N near Kayougue on the northern slopes of the Tibesti (Rioux 1960).

***Anopheles multicolor* Cambouliu.** This is one of the most widely distributed of the Libyan anophelines, with an epidemiological importance which is discussed later. The aquatic forms of *An. multicolor* tolerate extremely high salinities and also organic pollution (Kirkpatrick 1925, Barber and Rice 1937). In addition to brackish water in pans, ponds and pools in and around cultivated fields, larvae in Libya thrive in polluted collections of water in urban situations where high adult densities can maintain a significant level of man biting despite a preference for non-human blood.

***Anopheles rufipes broussesi* Edwards.** *Anopheles rufipes broussesi* is confined to, but well established in, the Wadi Tanezuft which, together with the neighboring Tassili N'Ajjers region of Algeria, represents the northern limit of its distribution (Gillies and de Meillon 1968). Larval sites in the Fezzan include overgrown pond edges, shallow wells and surrounding grassy overflows, as well as disused water tanks supporting growths of aquatic vegetation.

***Anopheles sergentii* Theobald.** *Anopheles sergentii* comprises two subspecies separable by fine larval differ-

[1] A misprint in the unpublished report of Kadiki and Ashref (1972) dates the 1935 record of *An. gambiae* as 1953. Vermeil (1953) was unable to find *An. gambiae* in the Fezzan, despite special searches.

ences (Mattingly and Knight 1956, Gillies and de Meillon 1968). The man-biting type form rests indoors or outdoors throughout its range, which includes the Middle East, the Arabian Peninsula, Africa north of the Sahara and some Saharan oases (Senevet and Andarelli 1956, Zahar 1974). The distribution of the Afrotropical *An. sergentii macmahoni* Evans, which does not bite man or rest in human dwellings (Gillies and de Meillon 1968) also extends into the Saharan oases (Senevet et al. 1959). Intermediate larvae difficult to assign to either subspecies occur in Algeria (Senevet et al. 1959, Rioux and Juminer 1964, Ramsdale and de Zulueta 1983) and have been noted by the present author in the Fezzan. The striking biological differences between the two subspecies raise questions about their present taxonomic status (Gillies and de Meillon 1968), the epidemiological importance of some Saharan populations of *An. sergentii* and the validity of the currently used morphological diagnostic characters (Ramsdale and de Zulueta 1983). The vectorial importance of Libyan populations of *An. sergentii* is considered later.

The larval stages of *An. sergentii* develop in a variety of non-saline collections of ground water, with or devoid of shade or aquatic vegetation. These include irrigation systems, seepages and shallow wells.

***Anopheles dthali* Patton, *An. rhodesiensis rupicolus* Lewis, and *An. pharoensis* Theobald.** These three species occur in adjacent territories (Ramsdale and de Zulueta 1983, Zahar 1974), but have not been recorded from Libya. Only *An. pharoensis*, a malaria vector in the Nile Delta in Egypt (Barber and Rice 1937), is of epidemiological importance.

Thus, a simple checklist gives a false picture of the Libyan anophelines, which may be more realistically classified as:

1. native desert species - *An. cinereus, An. multicolor, An. rufipes broussesi, An. sergentii;*
2. native species with limited coastal distributions - *An. algeriensis, An. labranchiae;*
3. exotic species possibly present in circumscribed situations - *An. tenebrosus, An. ziemanni;*
4. exotic transient species (records erroneous or unable to persist) - *An. gambiae s.l., An. marteri, An. superpictus, An. sacharovi, An. hyrcanus*;
5. species which may be expected to occur in Libya, but which have not yet been recorded - *An. dthali, An. rhodesiensis rupicolus* and, possibly in circumscribed situations, *An. pharoensis*.

**Recent changes in anopheline prevalence in the Fezzan.** Of six recorded anophelines, only *An. multicolor, An. rufipes broussesi* and *An. sergentii* appear to be endemic to the Fezzan. *An. rufipes broussesi* seems to be restricted to the Wadi Tanezuft. The others have wider distributions which, for epidemiological reasons, have been monitored over a period of some fifteen years, during which their distributions have become increasingly circumscribed. In 1983 neither *An. multicolor* nor *An. sergentii* could be found in any of the oases of the Wadis Etba and El Adjal, where they were formerly endemic, though both persist in the Wadi Chati, Hon - Wedden and Meduin - Zella groups of oases. *An. sergentii* is still a common mosquito in the oases of the Wadi Tanezuft.

Settlement and cultivation in the Fezzan is restricted to places where subsoil water can be tapped. A closed, naturally decaying aquifer, charged some 5,000 or more years ago (Jones 1964) when precipitation in the Sahara was considerably higher than now (Beadle 1974), underlies the Wadis Etba and El Adjal. Other Fezzanese oases depend upon different aquifers in which hydrostatic pressure is more than enough to make good losses to irrigation or even, as at Hon and Wedden, to provide artesian water.

Traditional irrigation systems in the Fezzan distribute water drawn by means of an animal powered bucket system from shallow open wells through a series of open channels and small storage reservoirs. These open wells and residual surface water in the irrigation network provide larval sites for *An. multicolor* and/or *An. sergentii*. The introduction of motorized pumps some 20-25 years ago allowed extraction of vastly increased volumes of water and cultivation of larger plots. Consequent lowering of the water table in the Wadis Etba and El Adjal necessitated substitution of the wells by deep, closed bores. Water is now pumped into straight sided, concrete tanks and distributed through open channels or, increasingly, through pipes to sprinklers which are more economical in the use of water. Even where open channels and flood irrigation are still practiced, the depressed water table and sandy soil ensure that residual surface water is quickly absorbed. The only standing surface water in oases in these wadis is now associated with sewage and is unsuitable for anophelines. Elsewhere, where oases are served by different aquifers, the water table is not affected by innovative irrigation practice and anopheline habitats are not adversely affected.

In addition to the aquifers already mentioned, reserves of water capable of sustaining a much larger human population underlie much of the Sahara (Beadle 1974, Gerster 1960). Large-scale exploitation of these reserves, as yet little realized in Libya, could profoundly affect anopheline prevalence. A newly created oasis in neighboring Algeria was quickly colonized by mosquitoes (Benabadji and Larrouy 1969).

**Malaria vectors and potential vectors in Libya.** The Fezzan has a long history of epidemic malaria, with many outbreaks of *P. falciparum* brought in by carriers in caravans coming from the south and transmitted by local vectors (Gebreel, unpublished). *P. vivax* was more prevalent near the coast. Most imported malaria at the present time is of *P. vivax*, though there are some cases of *P. falciparum*. Moreover, most current parasite carriers quickly disperse from the ports of entry (airports); there-

fore, all parts of the country are equally vulnerable.

Records of many recognized vectors exist, but only the desert *An. multicolor* and *An. sergentii sergentii*, considered by Macdonald (1982) to be the principal vector species, are sufficiently prevalent to maintain malaria transmission in most of Libya. Although direct proof is lacking, epidemiological evidence of the vectorial role of *An. multicolor* in many malarious situations is overwhelming, and this species is able to maintain a low level of transmission over long periods (Ramsdale and de Zulueta 1983). *Anopheles sergentii sergentii* played a major role in malaria transmission in the Middle East (Farid 1956) and has been an important vector of malaria parasites in the North African countries, including Libya (Zahar 1974). *Anopheles sergentii macmahoni* has not been recorded in Libya, but the presence of intermediate larvae in the Fezzan suggests that some desert populations may be of this form. However, until detailed investigation of the species allows clarification of the status of the various populations, it would be prudent to regard all as being of the vector form.

In contrast to the Magreb, where it was the principal vector of malaria parasites and where it is still responsible for residual foci of *P. vivax*, *An. labranchiae* in Libya is important only in a very restricted area. Almost all records of this and other marsh breeding mosquitoes are from a circumscribed coastal area around Touarga in Tripolitania. Other Palaearctic vectors for which occasional records exist are, at most, too rare to be of epidemiological significance and future creation of suitable larval habitats seems improbable.

Ramsdale and de Zulueta (1983) discussed the dangers of introduction of *An. arabiensis* and *An. gambiae* into the Hoggar and Tassili N'Ajjer following eventual completion of a paved trans-Saharan highway in Algeria and Niger. Colonization of the Tassili N'Ajjer by these species would also compromise the Fezzan, since less than 80 km separate the Djanet (Tassili) and Ghat (Fezzan) groups of oases. A more direct route by which these Afrotropical vectors might reach the Fezzan is from the Tibesti. Some 400 km separate the Gatrun oases of the southern Fezzan from Kayougue, where Rioux (1960) found developing larvae of *An. gambiae s.l.* Further extension of the paved road network will, inevitably, facilitate contact with countries to the south, increase traffic and cut journey times. Refutation of the previous record notwithstanding, the Fezzan is increasingly vulnerable to colonization by *An. arabiensis, An. gambiae* or both, but not to the exclusion of other resident species.

It must be concluded that, though *An. labranchiae* may be locally important in a circumscribed area around Touarga in Tripolitania, *An. multicolor* and particularly *An. sergentii sergentii* are the principal indigenous vectors of malaria parasites in Libya. Following the adoption of new methods of irrigation, prevalence of these two species has recently become more restricted in the Fezzan. This may be a temporary phenomenon and future developmental schemes based on water extracted from the deep reservoir underlying the desert might provide these vectors with many additional opportunities. Importations of Palaearctic anophelines are not seen as posing a malaria problem in Libya, but entomological vigilance must be concerned with possible invasions by the Afrotropical vectors *An. arabiensis* and *An. gambiae*, especially into the Fezzan.

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