VECTOR BIONOMICS IN THE EPIDEMIOLOGY AND CONTROL OF MALARIA

PART II

THE WHO EUROPEAN REGION AND THE WHO EASTERN MEDITERRANEAN REGION

VOLUME II APPLIED FIELD STUDIES

SECTION III: VECTOR BIONOMICS, MALARIA EPIDEMIOLOGY AND CONTROL BY GEOGRAPHICAL AREAS

(A) THE MEDITERRANEAN BASIN

PREPARED BY A.R. ZAHAR
VECTOR BIONOMICS

IN

THE EPIDEMIOLOGY AND CONTROL OF MALARIA

PART II

THE WHO EUROPEAN REGION

&

THE WHO EASTERN MEDITERRANEAN REGION

* * *

VOLUME II: APPLIED FIELD STUDIES*

SECTION III: VECTOR BIONOMICS, MALARIA EPIDEMIOLOGY AND CONTROL BY GEOGRAPHICAL AREAS

(A) THE MEDITERRANEAN BASIN

PREPARED BY

A.R. ZAHAR

FORMER WHO ENTOMOLOGIST

* Literature search ceased at the end of December 1989

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ANNEX 2: ABBREVIATIONS
INTRODUCTION

The series of PART II of VECTOR BIONOMICS IN THE EPIDEMIOLOGY AND CONTROL OF MALARIA

Document VBC/88.5-MAP/88.2 (issued in November 1988): VOLUME I: VECTOR LABORATORY STUDIES

Document VBC/90.1-MAL/90.1 (issued in April 1990): VOLUME II: APPLIED FIELD STUDIES

SECTION I: AN OVERVIEW OF THE RECENT MALARIA SITUATION AND CURRENT PROBLEMS

SECTION II: VECTOR DISTRIBUTION

Document VBC/90.2-MAL/90.2 (the present document issued in May 1990)

SECTION III: VECTOR BIONOMICS, MALARIA EPIDEMIOLOGY AND CONTROL BY GEOGRAPHICAL AREAS (see Fig. 1)

(A) THE MEDITERRANEAN BASIN

Document VBC/90.3-MAL/90.3 (in preparation)

SECTION III: VECTOR BIONOMICS, MALARIA EPIDEMIOLOGY AND CONTROL BY GEOGRAPHICAL AREAS (see Fig. 1)

(B) ASIA WEST OF INDIA

The same set of principles and the system shown in the PREFACE of VOL. I (pp. 6-10) have been observed when compiling information in VOL. II, with some modifications.

It should be emphasized that when new information is not available, resort is made to old knowledge to provide a background on the basis of which newer studies can be planned. Furthermore, depending on the availability of published or unpublished reports, the type and depth of information compiled may vary from country to country.

Where appropriate, it has been necessary to refer to the knowledge compiled in the series of PART I "THE WHO AFRICAN REGION AND THE SOUTHERN WHO EASTERN MEDITERRANEAN REGION". The series of documents of this part has been listed in ANNEX 1 in VOL. I.

As mentioned in the PREFACE OF VOL. I, results of the recent precipitin tests for the period 1971-1978 are quoted from the data annexed to the review of Garrett-Jones, Boreham & Pant (1980)\(^1\). Regarding vector resistance to insecticides, records are quoted from the lists compiled in the reports of the WHO Expert Committees of Vector Biology and Control respectively, (WHO, 1980 - TRS. No. 655, and WHO, 1986 - TRS: No. 737). More recent information is added from reports of susceptibility tests communicated to WHO/VBC by field investigators in several countries during 1984-1988\(^2\).

Information on the recent malaria situation by country are obtained mainly from WHO publications and data communicated to WHO/MAP by the WHO Regional Offices (EMRO and EURO).\(^3\) Additionally, country profiles constructed in a document entitled "Regional Malaria Information" by Dr G.A. Farid, WHO Regional Malaria Adviser, EMRO, are used for information on countries of that Region.\(^4\) Records of chloroquine resistance in P. falciparum in the Regions under review as mapped by WHO are reproduced. Immunological studies of malaria are beyond the scope of this compilation, but seroepidemiological surveys as part of malaria epidemiological studies are summarized.

\(^1\) Permission to quote these data was granted by the late Dr C. Pant and the Commonwealth Institute of Entomology (Dr J.M.B. Harley) in April 1983.
\(^2\) A computer printout of these reports was provided through the cooperation of Mr G. Shidrawi, VBC/VCT.
\(^3\) Copies of these data were provided through the cooperation of Mr J. Hempel, MAP/EME.
\(^4\) Permission to use information contained in this document was granted by the Regional Director, WHO/EMRO, Alexandria.
Due to language problems, it has not been possible to summarize adequately information published in Russian in the USSR. However, it was useful to find articles written in English by certain Soviet workers in the proceedings of a seminar entitled "International Scientific Project on Ecologically Safe Methods for Control of Malaria and its Vectors" published in Moscow (1980) - (Collected lectures, Parts 2 & 3). From these publications, certain articles have been summarized or a brief orientation to their contents has been made in the present issue.

At the end of this document, selected references are listed. Since the aim of this series is to assist newly assigned malaria workers to trace the source of information on their own or adjacent countries of similar conditions, the references are arranged by country in alphabetical order. At the top of the list, references dealing with subjects of general nature or covering several countries are placed first.

As mentioned in the PREFACE of VOL. I, it is impossible to define adequately the mathematical terms used by some authors in a reasonable space. Orientation to the relevant literature to be consulted is shown in ANNEX 1 in this document.

Some abbreviations have been used in this document, the glossary appears in ANNEX 2.

It is necessary to reiterate that literature search was made through screening the abstracts published in the Tropical Disease Bulletin (TDB) of the Bureau of Hygiene and Tropical Medicine, London, UK, and the Review of Applied Entomology (RAE), Series B, of the Commonwealth Institute of Entomology, London, UK. The efforts made by these institutions are fully acknowledged and greatly appreciated.

It should be explained that the preparation of this document was at the final stages in December 1989 before the disestablishment of the Division of Vector Biology and Control (VBC) and the Malaria Action Programme (MAP). Therefore, it has been decided to retain in the text the designation of the old units of VBC and MAP to which the WHO Officers who contributed to this document were formerly assigned. However, the names of these Officers are arranged in the Additional Acknowledgements according to their posts in the units of the new set up: Division of Control of Tropical Diseases (CTD).

1. Copies have been provided through the cooperation of Dr R.L. Kouznetsov, MAP/PAT.
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In addition to the Acknowledgements shown in VOL. I (document VBC/88.5 − MAP/88.2) grateful thanks are expressed to the following colleagues in various institutions and WHO for their valuable contribution to the present and preceding issues, and to authors and copyright authorities for granting permission to reproduce illustrations and/or data from published papers:

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Mr C.D. Ramsdale, former WHO Technical Officer, for providing an advance copy of the manuscript of his paper on "Anopheles Mosquitoes and Imported Malaria in Libya", and for granting permission to reproduce a map of Libya and for exchanging views and redrawing the map of Libya and the map of seasonal population movement in Turkey.

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Dr J.D. Allen, Promotions Controller, for C.A.B. International, Oxon, UK, for permission to use certain abstracts from the RAE.

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Dr S. El-Said, Principal Investigator, Research & Training Center on Vectors of Diseases, Ain Shams University, Abbassia, Cairo, Egypt/Dr Ronald A. Ward Editor Journal of the American Mosquito Control Association, Washington, USA.

Mr N. Eshghy/Tropical Geographical Medicine, Amsterdam, the Netherlands.

Dr M.A. Farid, former WHO Malariologist/Ms Martha Strassberger, Rights and Permissions, Academic Press, Orlando, Florida, USA.

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SECTION III: VECTOR BIONOMICS AND MALARIA EPIDEMIOLOGY AND CONTROL BY GEOGRAPHICAL AREA

(A) THE MEDITERRANEAN BASIN (Fig. 1)

This area is bounded on the north by a group of countries of Mediterranean Europe: from west to east: Spain, France, Italy, Yugoslavia, Albania, Romania, Bulgaria, the USSR, close to the Black Sea, Greece and Turkey (with Malta added to this group); and in the south by countries of the North African coast; from west to east: Morocco, Algeria, Tunisia, Libya, and Egypt; and in the east by: Syria, Lebanon, Israel and Jordan with Cyprus added to this last group.

Subsection (i): VECTOR BIONOMICS

The main vectors of the Mediterranean Basin dealt with here are: members of the An. maculipennis complex, An. superpictus, An. sergentii, and An. pharoensis. Of the secondary and suspected vectors reference will be made to the An. hyrcanus group, the An. claviger group, An. hispaniola, An. d'thali and An. multicolor. The book of Senevet & Andarelli (1956) represents a valuable source of basic knowledge of the taxonomy, distribution and biology of the anophelines of North Africa and the Mediterranean Basin, from which certain information will be recapitulated when newer information is not available. Similarly, in the absence of newer studies on certain aspects of vector bionomics, information will be briefly cited from the book of Horsfall (1955) which well documented the old knowledge as studied by various workers during the 1920's-1940's. For certain vectors, specific information will be compiled from the review of Zahar (1974) and Service (1986) as necessary.

A useful review has been presented in English by Artemiev (1980). This will be used as a main source of information on vector bionomics in the USSR, although it deals with whole republics and territories of the USSR and not necessarily the Black Sea area.

1. The Anopheles maculipennis complex

1.1 Vector importance

All members of the An. maculipennis complex are potential vectors in continental Europe. As shown under SECTION II in document VBC/90.1-MAL/90.1, An. sacharovi is an important vector in Turkey and Syria, and has recently reappeared in Israel and still exists in Jordan and is regarded in both countries as an important potential vector. An. labranchiae has been regarded as the main vector of malaria in Morocco, Algeria and Tunisia and is now responsible for malaria transmission in small persistent foci in Morocco.

1.2 Breeding habitat

It is useful first to recapitulate in the following the basic knowledge of the breeding habitat of members of the An. maculipennis complex from Senevet & Andarelli and subsequently add the available newer information.

- maculipennis s.s. (=typicus): Its typical breeding habitat is in cold waters occurring in upland regions, but this species was also encountered in areas close to sea level associated with meseaee in running waters. It was also recorded in warm waters as for example, certain areas surrounding Naples, Italy.

- meseaee: It is rarely found in waters containing more than 1.5 g NaCl/l. It prefers shaded breeding places. It is generally associated with typicus and melanoon.

- melanoon: It breeds in freshwater and rice fields (north of Italy). It also breeds in marshes and swamps (oriental coast of Spain).

1. It should be noted that some information summarized here deals with investigations carried out in areas and localities of the Occupied Territories.
- subalpinus: It breeds in fresh water or slightly saline as in sunlit swamps and ponds with vegetation, but avoids small shaded breeding places. It also breeds in rivers and streams as well as rice fields. In the spring it prefers the stagnant waters overlapped with horizontal vegetation. In summer, its eggs, as in the case of typicus and messeae, are easily identifiable, while in the spring and autumn they are less recognizable (black in colour).

- labranchiae: The breeding places are very variable: swamps and rivers overlapped with vegetation, holes, canals, marshes, basins etc. In general, it prefers sunlit breeding places.

- atroparvus: It breeds in brackish or freshwaters and prefers well-lit breeding places (Portugal and Spain).

- sacharovi: It breeds in all small water collections containing aquatic vegetation.

Service (1986) gave a general description of the breeding habitat of certain members of the An. maculipennis complex as follows: An. atroparvus breeds in sunlit, exposed pools and ditches with either fresh or brackish water, as well as rice fields. An. labranchiae breeds in brackish waters in coastal marshes, fresh waters of rice fields, marshes and edges of grassy streams and ditches; it prefers sunlight. An. sacharovi breeds in fresh or brackish waters of coastal or inland marshes, pools, ponds, especially those with vegetation; it prefers sunlit habitat.

In France, Cousserans, Salieres & Tesson (1974) recorded for the first time An. maculipennis s.s. (= typicus) in the Montpellier area and described its breeding habitat in the Lez river at the northeast of the town. The river was extremely slow moving as a result of the very dry summer of 1973. The lower reaches of the stream were overlapped with dense vegetation composed of Potamogeton natans with patches of Scirpus lacustris. The analysis of water of the river differed from that of the natural breeding places of An. subalpinus which were frequently encountered in the Hérault and Les Bouche-du-Rhône. The analysis showed: pH 7.8; Cl 71 mg/l; organic material (in mg O2/l): of animal origin, 1.3 and vegetable origin, 7.5. In this biotope, maculipennis s.s. was associated with and predominated over subalpinus. The presence of maculipennis s.s. in this Mediterranean sub-region is a significant finding from an ecological standpoint, taking into account that the classical biotope of this species was described as cold water in higher regions (citing Senevet & Andarelli, 1956) [It should be noted that Senevet & Andarelli at the same time indicated that maculipennis s.s. was encountered in running waters at sea level but less frequently, and also in warm waters.]

Also in France, Pichot & Deruaz (1981) presented the results of identification of the An. maculipennis complex collected in the Lyon region. The presence of messeae was confirmed while maculipennis s.s. was recorded for the first time. The presence of atroparvus was suspected and should be checked by further studies, and careful vigilance on anopheline fauna should be implemented because of the risk of malaria transmission from gametocyte carriers. On the larval ecology, the authors found that maculipennis s.l. was widespread and abundantly present at Brome in surveys made during 1972-1974. The larvae were collected from permanent breeding places, principally around ponds, along rivers and swamps. The large-sized breeding places were sun-lit and overlapped with vegetation such as: Sparganium sp., Phragmites communis, Lemma minor and Juncus sp. Development of the immature stages occurred between the end of March and October. The larvae were associated with An. claviger and Culex spp. The water of the breeding places was clear, colourless, generally neutral (mean pH 6.95) and warm (mean temperature 20.46°C). During 1977-1978, surveys made in Bas-Dauphiné and Crémieu island showed that larvae of maculipennis s.l. were breeding in similar situations.

In Italy, Bettini et al., (1978) drew attention to the potential implications of extension of rice cultivation in the central part of the country [see SECTION I, under 1.2.1, (i) in document VBC/90.1-MAL/90.1]. Some more details of the surveys carried out by these authors are given here. In the past, An. labranchiae had been the most important malaria vector in the coastal plains and the inland hills of central Italy. In 1947, DDT house spraying was applied in the malariatic areas of Tuscany and North Latium of Maremma Region, resulting in interruption of malaria transmission. At San Donato (Grosseto, Tuscany), a locality previously known to be highly malariatic, few adults of labranchiae
were found after spraying, the last specimens were collected in 1958, thus the species appeared to have been eradicated from the Maremma region, except for one locality in the extreme south (citing Coluzzi & Finizio, 1966). Regular searches for adults of the An. maculipennis complex carried out in Grosseto province showed only a constant presence of melanoon in rice fields about 3 km from the sea, and low densities of messaeae (citing Majori et al., 1970) and atroparvus (citing Coluzzi & Finizio, 1966). Rice had never been cultivated in San Donato locality or its surroundings until 1975 when it was grown experimentally in a small area. In 1977, rice was grown in 65 hectares around the locality without the permission of authorities. An entomological survey was carried out in August 1977 in paddy fields and was extended later to the surrounding rice-growing areas. Adults of maculipennis s.l. were abundantly found in animal shelters close to paddy fields. In the fields, a large proportion of the larvae collected showed morphological characters corresponding to those of labranchiae. The larval density was as high as 10-50 larvae/dip. Based on the egg characters, 237 ovipositions raised from females of maculipennis s.l. collected from stables in San Donato during August-September were identified as follows: 40.5% labranchiae, 55.3% melanoon, 3.4% messaeae, 0.8% maculipennis s.s. From 690 ovipositions from the area surrounding San Donato, 31.5% were identified as labranchiae. The percentage of farms positive for labranchiae was lower in the surrounding area (59.5%) than in San Donato itself (82.8%). The foci of labranchiae covered about 30 km². Before malaria eradication, rice cultivation was accepted as a means of land reclamation on account of the alleged preference of non-vector species for freshwater, in contrast to the adaptability of vector species, labranchiae and saccarovi to brackish water (citing Hackert, 1944 and Pampana, 1944). Citing Celli (1934) and Pampana (1944), the water in rice fields during the first years of cultivation would maintain a sufficient salt concentration, thus becoming suitable for the vectors. However, four water samples collected randomly from paddy fields at San Donato showed very low chloride concentration values (46, 40, 41 and 78 g/l), thus confirming that labranchiae breeds in fresh water as well as brackish water (citing Pampana, 1944). The present findings illustrate how uncautious farming policy can lead to rapid increase in vector density, to levels higher than those observed before DDT spraying, with the risk of re-establishment of malaria transmission in the presence of imported cases.

In Sardinia, Marchi & Munstermann (1987) reported the results of a 5-year survey conducted to determine the changes in mosquito fauna 35 years after the malaria eradication campaign. As a result of the anti-mosquito campaign known as: Ente Regionale per La Lotta Anti-Anofelica in Sardegna (ELAAS) that was carried out during 1947-1950, malaria was effectively eradicated from the whole island. The campaign was directed almost exclusively against the principal vector, An. labranchiae, by applying DDT house spraying and land reclamation. Since the long-term effects of the campaign on the mosquito fauna have scarcely been investigated previously, the authors carried out the survey during 1980-1985 to fill this gap in knowledge. In recent years an increasing number of imported malaria cases have been reported in Sardinia. Insecticide pressure, although on a very reduced scale, has been maintained in a number of the more widespread anopheline foci, and extended to include several major mosquito pests. With the expanding urbanization and changes in farming practices, profound alteration of the natural habitats have occurred, especially along the coast. The basis of comparison of the mosquito fauna was the thorough study of the Sardinian Culicidae by Aitken (1954). Data of mosquito species of six genera: Culex, Aedes, Culiseta, Orthopodomyia, Coquillettidia, and Anopheles were presented. The species composition was similar to that recorded during the years of the eradication campaign, except for the genus Anopheles. Of the eight Anopheles species previously recorded, only four were identified in collections of 1159 larvae from 85 positive sites. An. labranchiae was the most frequently encountered anopheline, but represented only 12% of the total collections of mosquitoes. Comparison with previous records indicated a progressive increase in sites positive for this species over the past 35 years. Larvae of labranchiae were always found in freshwater. Anopheles hispaniola was not encountered, although it had apparently replaced labranchiae soon after the eradication campaign (citing Aitken & Trapido, 1961). Larvae of labranchiae were common in the sites where the replacement phenomenon had been observed.

D'Alessandro, Bruno-Smiraglia & Lavagnino (1971) when presenting their studies on the biology of An. labranchiae summarized the history of malaria eradication in Sicily and recapitulated the breeding habitat of this species as the principal vector of malaria in the island. Large scale DDT house spraying which began in 1947 was gradually reduced from 1960 onwards with the exception of limited areas. Ten years have elapsed since the last
An indigenous malaria case was recorded, and different forms of vigilance activities have been maintained in the formerly endemic zones. *An. labranchiae* existed at sea level as well as at higher altitudes; the highest altitude being 1720 m in Monte Soro, Messina. Its larvae can be found in river pools, brooks, marshes, puddles and spring-water. Cool, sunlit, slow moving fresh water are preferred. A moderate salinity of the water is tolerated.

In their presentation of a cytogenetic study for comparing *An. sacharovi* populations existing in Italy and Turkey, Petrarca et al. (1980) [see VOLUME I, under L.L.z, p. 33] described the breeding habitat of this species. The Italian *An. sacharovi* formerly a vector of malaria was drastically reduced through residual house spraying or through the effect of pollution in the littoral swamps which had been a typical breeding habitat of this species. *An. sacharovi* still exists in Puglia on the Adriatica and probably in Sardinia, but does not reach a high density. In contrast, the Turkish *An. sacharovi* which is an important vector causing severe malaria epidemics breeds especially in freshwater inland and extends its existence to areas of over 500 m altitude (see more details below under Turkey).

In Yugoslavia, Lepeš & Vitanović (1962) following a malaria epidemic that occurred in 1959 in Stojaškovo village, Bogdanci municipality, southeast Macedonia, carried out an entomological investigation in this area during 1960. In addition to recording several members of the *An. maculipennis* complex (*maculipennis* s.s., *atroparvus*, *messelae* and *subalpinus*), the authors discovered the presence of *sacharovi* in four settlements close to the Greek border. As *sacharovi* had never been reported previously from Macedonia, they suspected that it must have migrated across the border from Greece. Differences in the proportions of *sacharovi* found in various settlements was attributed to the degree of water salinity of the breeding places; high salinity being necessary for the development of the immature stages of this species. At Bogorodica village for example, the water salinity in one of the breeding places (a pond of about 1.5 ha), reached 74 mg/l, and *sacharovi* accounted for 69% of the anopheline larval population, while at Palurci village where the water salinity was 15-18 mg/l (the normal percentage of salinity in freshwater) *sacharovi* larvae constituted only 2.6%.

In Romania, Duport et al. (1974) when presenting their studies on the impact of insecticidal spraying on the anopheline vectors of malaria summarized information on the breeding habitat of the four previously recognized vectors as follows:

- **atroparvus**: As its larvae prefer brackish water, it predominates in the inland as well as the littoral zones.
- **messelae**: As its larvae thrive in freshwater, it is found in the plains breeding sometimes in small collections of water, but abundantly in ponds, lakes as well as in hilly areas where it breeds in slow-running well-aerated freshwater streams.
- **sacharovi**: This Mediterranean species is encountered in a very limited zone forming a band of 10-15 km along the littoral part of the Black Sea. In the past, this species had been responsible for explosive malaria epidemics in the eastern part of Constanta and Tulcea districts. It is now considered a vector of minor importance because of its very limited distribution. The drastic reduction of *sacharovi* populations and even its disappearance from Romanian littoral has apparently resulted from "desalinization" and drainage operations carried out in several lakes as well as from the application of insecticides.

Bilbie et al. (1983) during their investigation on the response of potential malaria vectors to insecticides in previously malarious areas in the Danube plain and Dobruja, Romania during 1981-1983, observed mosquito fauna in rice plantations. In Orădilea rice plantation, no or few mosquito larvae were observed in May-June due partly to the application of insecticides during the first phases of rice development, and partly to the intermittent irrigation scheme (i.e., temporary flooding during 24 hours and followed by water drainage during 3-5 days). Under these conditions, *Culicidae* larvae were found at a reduced density (0.5 larvae/dip, using a dipper of 8.5 cm diameter), with anopheline larvae constituting 90%. In July-September, when the rice plots were permanently flooded, the larval densities remained low 0.8-1 larva/dip) with the anophelines constituting 95%. The irrigation canals are sloped and have strong water velocity due to pumping, hence not
suitable for larval development. On the contrary, drainage canals which discharge the water from rice plots, are broad and not sloping, thus having slow water current and are often overgrown with emergent and submerged vegetation. Therefore, they provide a favourable habitat for larval development. At the end of June, a mean density of 1.7 larvae/dip was found in these canals with the anophelines constituting 76% and the culicines 24%. In July-August, the density increased to 5.3 larvae/dip with the anophelines constituting 99%. During the same period species identification based on the characters of the eggs which were raised from anopheline females collected from shelters at two nearby villages showed that 86% were messeae and 14% maculipennis s.s. In another irrigated area (Schira), while the mean density was 0.2-1.1 larvae/dip in May-June, it increased to 4.2 larvae/dip in July-August of which 48% were larvae of anophelines. The species composition was: 78% messeae, 15% atroparvus and 7% maculipennis s.s.

In the USSR, Artemiev (1980) included in his presentation on the main malaria vectors of the Soviet Union, notes on the breeding habitat of members of the An. maculipennis complex as follows:

- **maculipennis s.s.**: breeds in streams or beds of mountain rivers. Larval development occurs at temperatures between 10 and 35°C, with the optimum being 25-30°C. At temperatures below 7.5°C or above 35°C, larvae become torpid. Larvae may gradually get frozen in ice and can tolerate lowering of temperature to -10°C for several hours. Prolonged exposure to ice or an increase of temperature to more than 45°C kills the larvae. Breeding occurs in bodies of water rich in oxygen. Polluted waters particularly those with high nitrogen content are avoided. The maximum salinity tolerated by the larvae is 9%. Larvae can tolerate waters lacking salts better than do other species of the complex. When calcium salts are present in the water, larval breeding improves considerably. The presence of aquatic vegetation is also favourable although larval breeding can successfully occur in waters devoid of vegetation provided that the water is pure. Larvae have been frequently encountered in shallow water of slate-covered beds of mountain rivers completely devoid of algae and other vegetation.

- **melanoon and subalpinus**: Artemiev (loc.cit.) remarked that Soviet entomologists rarely drew distinction between these two forms, and thus the ecological and biological observations reviewed by him are equally applicable to both subspecies. [Evidence has now been provided that subalpinus is a good species distinct from melanoon – see Bullini & Coluzzi (1982) and Cianchi et al. (1987) in VOLUME I, under 1.1.2, pp. 36 & 38 respectively]. The larvae breed in stagnant freshwater bodies rich in aquatic vegetation. The chemical composition of the water is similar to that of maculipennis s.s., but the two species are more salt-tolerant, and at the same time they can readily survive in salt-free waters. Temperature requirements are similar to those of maculipennis.

- **atroparvus**: Larvae develop in standing waters, often brackish and usually containing aquatic vegetation. They can tolerate salinities up to 14%, but the best development occurs in slightly brackish water having a salinity ranging between 3 and 10%. Larvae of atroparvus are less tolerant to salt-free waters than maculipennis s.s. but are more tolerant to waters deficient in calcium salts. The temperature requirements are similar to those of maculipennis s.s.

- **meseae**: Larvae develop in standing non-saline waters overgrown with vegetation in the plains. The temperature requirements are similar to those of maculipennis s.s.; larvae become torpid at 5°C and 40°C. The optimum temperature is between 25 and 30°C. Larvae of messeae are sensitive to water salinity and cannot develop in water with a salinity above 3-6%, i.e., they are less tolerant to salinity than maculipennis s.s. The optimum salinity is 1-2%. The larvae of messeae cannot develop in polluted waters.

- **beklemishevi**: Previously this species was taken as maculipennis s.s. existing in lowland and highland areas of Russia and Siberia. Based on cytogenetic studies of the polytene chromosomes and egg morphology, the species was described and named beklemishevi. Ecologically, it is close to messeae, but the two species are reproductively isolated. [See Stegini & Kabanova (1978) in VOLUME I, under 1.1.2, pp. 28-29]. The information on the ecology of maculipennis s.s. in the north of the USSR actually relates to beklemishevi.
In Central Asia, larvae of this species can develop normally in bodies of water where the temperature rises to 38–40°C in daytime. Its breeding habitats are quite variable: puddles, ditches with standing water, canals, boggy areas, coastal marshes of ponds and lakes etc. High salinity is well tolerated by the larvae of sacharovi than any other member of the An. maculipennis complex; its larvae can develop in waters having salinities up to 20%. Distilled water cannot be tolerated. High NaCl contents are needed, even if calcium and magnesium salts are present.

In western Georgia, Sichinava, Stegni & Sipovich (1983) studied the distribution and the biology of An. maculipennis s.s. and An. subalpinus. The immature stages of maculipennis s.s. developed in water reservoirs with sandy or stony bottoms, while those of subalpinus developed in biotopes with peat or clay beds.

In Turkey, Postiglione, Tabanlı & Ramsdale (1973) pointed out that in view of identification difficulties, it was not possible to define exactly the ecological requirements in the larval habitat of individual members of the An. maculipennis complex. The recorded habitats of the three members of the complex that occur in Turkey: maculipennis s.s., subalpinus and sacharovi, include brackish and freshwater in swamps, excavations, open reservoirs, irrigation and drainage canals, roadside ditches, and rice fields. Horizontal or emergent vegetation is invariably present. High densities of all three species occur at sea level and regular breeding can be seen up to an altitude of 2300 m in the case of maculipennis s.s., and about 1200 m in the case of subalpinus and sacharovi, although a single record indicated that sacharovi was found at an altitude of 1720 m (citing Gokberk, 1961). However, this species has been unable to establish itself at this altitude. Identification of eggs collected from breeding places in Turkey has shown that although each species can occur in pure cultures, two or even all three species utilize the same habitat in certain areas. Thus, all three species were found breeding in flooded rice fields in the Meric valley, Edirne province on the Greek border. In contrast, subalpinus and sacharovi were extremely rare in the rice-growing area of Biga, Canakkale province, south of the Marmara sea, where maculipennis s.s. was abundantly present. On the other hand, maculipennis s.s. was virtually absent from the shores of lakes Eber and Aksehir, Afyon and Konya provinces on the central Anatolian plateau, where high densities of subalpinus and sacharovi occurred. In this area, subalpinus was dominant in some places, while sacharovi was dominant in others. The degree of dominance of sacharovi may often depend on water salinity, but salinity is not necessarily the determining factor, since it was the dominant species throughout the year in many freshwater inland and coastal habitats. Nothing is known about the factors determining the relative abundance of maculipennis s.s. and subalpinus. Although maculipennis s.s. is known to be a highland species, it was the dominant species at sea level.

In Morocco, Guy (1963) in his account of the epidemiology of malaria in the country incorporated notes on the biology of the vectors. The classical breeding habitats of the main vector An. labranchiae were described as sun-lit ponds overgrown with vegetation as well as rice fields where a large density of larvae was encountered.

In Algeria, the only available description of the breeding habitat of An. labranchiae comes from a long study (1932-1956) in the region of Alger reported by Collignon (1959). The habitat of An. labranchiae (shown as An. maculipennis var. labranchiae) was classified into: the habitat of the plain and the habitat of the mountains as summarized in the following:

- The habitat of the plain: In general, the typical habitat is a depression isolated or linked with a water course. The water which is retained for a sufficient time is characterized by being fresh, clear, shallow, and slightly exposed to the action of the wind and variation in its depth. The type of aquatic vegetation whether floating or emergent plants depends on the depth of the water. While Ranunculus and Potomogoton are common, emergent Ceratophyllum is seen in pools with sufficient depth. Larvae of labranchiae avoid sites close to crucifer plants, and they are often absent in waters having floating Lemna. It seems that this is not due to the presence of the plant itself but to the pollution of water which deters the ovipositing females. Waters shaded by a dense growth of emergent vegetation such as Typha or aquatic grasses are less favourable to the larvae.

- The habitat of the mountain: In the hilly regions, which drain into the plains, water courses with gravel and pebbles offer another type of breeding habitat for
labranchiae. This habitat contains little vegetation, except for some filamentous algae. Larvae can also be found in residual pools or the blind ends of streams whenever water stagnates and has a suitable temperature for development. The larvae avoid the algae sites. Their density is much less than that found in the breeding places of the plain. Breeding places of the mountainous region are usually situated close to human agglomerations.

The presence of labranchiae in the habitats of the plains and the mountains indicates the wide distribution of the species in the Alger region from the sea to Sidi Saada.

No newer information in the breeding habitat of labranchiae in Algeria could be traced.

In Tunisia, Juminer (1959) in his notes on the anophelines of the country described the breeding habitat of labranchiae as being brackish or actually saline water without any trace of vegetation. No newer information could be traced.

In Libya, records of anopheline fauna were reviewed by Macdonald (1982). An. labranchiae was recorded from Taoura and it seems that Tripolitania is its eastern limit. It breeds in fresh and brackish water of rivers and marshes, especially where there is some shade.

In Cyprus, before the Anopheles (malaria) eradication campaign that was launched in 1946, An. sacharovi and superpictus were regarded as the main vectors of malaria. Under the eradication operations, sacharovi was eradicated but superpictus persisted at a very low density. It should be recalled that malaria eradication in Cyprus was officially certified in October 1967 [see Document VBC/90.1–MAL/90.1 – SECTION I, Table 1 under 1.1]. Zulueta (1974) in an unpublished report to WHO pointed out that despite the proximity of the Turkish coastal areas to Cyprus (less than 80 km) the reintroduction of sacharovi into Cyprus through ships seems unlikely because the former breeding places of this species have been radically changed by land reclamation and agricultural development. Thus, it seems difficult for sacharovi to re-establish itself on the island, but the potential danger, nevertheless, must be kept in mind. From more recent information compiled by Shidrawi (1983) no sacharovi has been found in entomological surveys up to 1982 since its last record in 1952.

In Jordan, the only member of the An. maculipennis complex is An. sacharovi. Farid (1954) in his article on the effect of DDT house spraying on malaria transmission in the Jordan Valley, included notes on the bionomics of the maoni vectors. An. sacharovi was recorded in large numbers in premises in the northern part of the Jordan Valley. It was found to breed in residual pools along the river and perennial streams, as well as in a few springs located in the foothills. Its prevalence in the valley decreased towards the south.

In Israel, the only member of the An. maculipennis complex is An. sacharovi. In the past, Salternik (1957) presented his comprehensive observations on this species as an important vector of malaria in the country. During 1938-1942, the ecology of the aquatic stages of sacharovi was studied in 38 different breeding places. The breeding occurred in valleys comprising water-filled pits, along river banks, neglected fish ponds, wide canals, blind ends of streams that are almost stagnant or with a very slow current sunlit or covered by horizontal vegetation. In hilly areas, breeding was occasionally found in rain puddles. Larvae were generally distributed among floating horizontal vegetation. Optimum conditions for breeding of sacharovi were shown to be:

- water depth generally over 30 cm;
- current absent or very weak;
- pH ranges from 7 to 8.8;
- temperature between 10 and 36 °C with the optimum being 21-25 °C;
- water exposed to sunlight;
- salinity not higher than 0.7%;
- vegetation of the following types:
  (a) with roots, floating vegetation: Potamogeton and Ranunculus.
  (b) rootless, floating vegetation: Myriophyllum and Ceratophyllum.
  (c) floating, filamentous algae.

No breeding was found in waters with dense cover of Lemma minor, L. vulgaris, Nymphaea caerulea, Nuphar luteum and Jussiaea repens.
In his review of the historical distribution and bionomics of malaria vectors in Israel, Saliternik (1974) summarized the breeding habitat of *sacharovi* as being stagnant or slowly moving waters of swamps, ponds, pools and rivers, covered by some specific horizontal aquatic vegetation. Breeding and adult densities of *sacharovi* decreased gradually and the species disappeared completely during 1960-1971. The factors that influenced the elimination of this most dangerous vector were:

(a) drainage of all important swamps in the country;
(b) wide areas of stagnant water collections have dried up because their level sank through extensive pumping of underground water;
(c) unsuitable conditions for breeding in streambeds were created by sewage pollution;
(d) *sacharovi* population being an endophilic species was greatly affected and reduced by wide-scale DDT house spraying.

Saliternik concluded that *sacharovi* has almost been eradicated and has no vectorial importance in Israel.

Ben-Dov (1971) reported the reappearance of *An. sacharovi* as it was identified in samples collected during routine surveys of potential breeding places carried out by antimalarial inspectors of Tiberias district. This region was not under Israeli administration prior to June 1976, and no information was available on anopheline breeding before then. Of 91 larval samples collected from this area and other localities, three included larvae of *sacharovi*: Buteilha valley, Ramot (spring), Ramot (swamp), and a spring near the entrance of the Jordan valley into the sea of Galilee.

Following the above report, Pener & Kitron (1985a) started to monitor *An. sacharovi* populations in Israel from 1970 to 1984. Based on the identification of larvae collected routinely by the antimalarial inspectors and information collected by the authors on the breeding habitat and ecological conditions, *sacharovi* larvae continued to increase from 1971 when they were found at three sites, until 1984 when they were found 20 times in one year. The increase was particularly marked between 1978-1979 and 1984. During this period *sacharovi* density increased by 6-fold to become the second most common *Anopheles* species (after *An. claviger*) found in northern Israel. Most of the breeding sites of *sacharovi* (75.9%) were located at the margins of streams and springs. The remaining breeding sites were nearly all in standing water habitats, such as swamps, fish ponds and seepages.

In Lebanon, *An. sacharovi* is the only member of the *An. maculipennis* complex present. Graniccia (1953) in his presentation of the malaria situation in different regions of Lebanon, included notes on the bionomics of the main vectors. The breeding places of *sacharovi* were described as being sunlit stagnant water collections in swamps or semi-stagnant at marshy banks of rivers or along the large irrigation canals. The breeding waters of this species in Lebanon were always fresh, unlike its habitat in certain countries of Europe where it breeds in brackish waters.

In Syria, Abdel-Malek (1958) reported the results of a survey of anopheline mosquitos in the northern part of the country, which was carried out during March 1953 - December 1954. Starting from Homs, the survey was extended to the northwest covering the governorate of Hama, Aleppo, and Lattakia up to the Turkish border in the north. The survey was also extended to the northeast covering the governorates of Euphrates and Gezira up to the border of Iraq in the east, and the Turkish border in the north. *An. sacharovi* was found to be the most predominant anopheline species. Larvae were usually encountered in stagnant waters of marshes exposed to the sun for most of the day. These breeding places had mats of floating and filamentous algae. Such breeding places were common in the area around Homs town. From these places larvae of *sacharovi* were associated with those of *superpictus* during April-September 1954. *An. sacharovi* was also found breeding in semi-stagnant waters along banks of marshy rivers and around lakes. These breeding sites were overgrown with a great mixture of aquatic vegetation, emergent herbaceous plants such as grass and reeds with patches of floating vegetation. Such breeding places were common around Homs lake where larvae of *sacharovi* were found alone or in association with those of *hyrcanus* and *superpictus*. Under the same conditions larvae of *sacharovi* were also encountered in association with those of *superpictus* in swamps on the Mediterranean coast near the mouth of Nahr-es-Sinn about 30 km from Lattakia. This type of breeding habitat was also seen in the Ghab which was regarded as the largest
inland swamp formed by the Orontes river. Larvae of sacharovi were also found in neglected irrigation canals in the vast area surveyed. Such a breeding place was encountered in many villages in Dirik, Qamichieh, Hasakeh, Deir-el-Zor areas in the northeast where sacharovi larvae were associated with those of superpictus. It was only in two villages namely Aarboushe in Hasakeh, and Souar in Deir-el-Zor (Euphrates) areas that larvae of sacharovi were associated with those of superpictus and pulcherrimus. The same type of breeding places was also observed in many villages along the Orontes river in Homs and Hama governorates. Rice fields provided a favourable breeding habitat for sacharovi in the Aleppo area and along the Homs-Tripoli road. Water in all breeding habitats of sacharovi encountered was fresh. No newer information could be traced from Syria.

1.3 Swarming and mating

Most of the knowledge on swarming and mating of the An. maculipennis complex comes from the early observations carried out during the 1920's-1940's. These have been reviewed in the book of Horsfall (1955) and should be read in the original. On the mating behaviour, it can be briefly stated that as also summarized by Senevet & Andarelli, 1956) maculipennis s.s. and messeae are eurygaEous while atroparvus is stenogamous.

Recent information on swarming and mating of An. maculipennis complex that could be traced is very limited. Artemiev (1980) in the USSR states that males of atroparvus follow the females everywhere to the extent that their proportion in a collection may reach 60%. Copulation may occur indoors, and for this reason this species can be cultured in the laboratory, although this is more difficult to achieve compared with atroparvus.

Kasap & Kasap (1983) explained that sacharovi is difficult to colonize in the laboratory, partly due to the behaviour of the males which swarm before mating; field observations in Turkey showed that males were seen swarming above water or above any other object which is 1.5-2 m high. [See attempts to colonize sacharovi in the laboratory in VOL. I, under 2.1.2, pp. 64-66]

1.4 Dispersal

Horsfall (1955) also reviewed the old observations reported by early workers during the 1920's-1940's on the dispersal of An. maculipennis complex, particularly atroparvus and maculipennis in the Netherlands, for which the book should be consulted. With regard to labranchiae, Senevet & Andarelli (1956) gave its range of flight as 2-5 km depending on the place and the associated conditions such as the presence of a light breeze, the existence of trees etc.

In Algeria, Collignon (1959) working in the Alger region observed that the location of the resting sites of labranchiae depends primarily on their distance and altitude in relation to the breeding places. The dispersal range of this species is usually limited and concentrated around the breeding source. The resting sites situated at a distance of less than 100 m from each other in straight perpendicular lines from the breeding sites usually harbour decreasing densities of labranchiae as the distance from the breeding source increases. Most frequented resting sites are those situated within 400 m, and the least frequented are those occurring at 800 m or more from the breeding place. Height is repugnant to labranchiae as it became more scarce in higher storeys of buildings. Moreover, houses of populations of north Algeria situated on hills are less frequented by labranchiae, and remain free of autochthonous malaria. This actually benefited the original inhabitants of the mountains who came to settle in Métilidia, after the drainage of the [littoral] plains allowed them to settle indefinitely.

In Israel, Saliternik (1957) reviewed the early observations on the dispersal of sacharovi. During the spring and summer the resting places and feeding sites of sacharovi are not very far from the breeding places. In June 1924, about 2000 wild-caught adults of sacharovi were marked with methylene blue and released in the Shomron plain, (citing Shapiro & Saliternik, 1930). After three days marked mosquitoes were found in houses in Hederia, a village situated at 2.5 km from the release point. In general the majority of mosquitoes appear in the village closest to the breeding places, and in such villages they are concentrated in the houses closest to the breeding sites. If the breeding places are far from the blood source, the dispersal flight can exceed the normal range, reaching 3.5 km from the breeding places. In such cases, the number of male and young female
mosquitoes is proportionally reduced as the distance from the breeding place increases. In the late autumn when the main purpose of the dispersal flights is to seek suitable sheltered resting places for hibernation, the distance of dispersal flights may be much greater. In Huleh valley, large numbers of sacharovl entering hibernation were found to cover distances reaching six times their normal summer flight range, (citing Reitler & Saliternik, 1929). In this particular area, numbers of sacharovl were found in Rosh Pina, a village situated at 14 km from the nearest breeding place. Many infected females were included in those migrating populations (citing Kligler & Mer, 1931). Dispersal flights were found to occur in two waves: the first in October comprising approximately 35% males, and second at the beginning of November containing 15% males, and the latter flight reached greater distances. By the beginning of December the males disappeared and the females were found fertilized, but their ovaries were underdeveloped, and large fat bodies were formed. If some of these mosquitoes are infective, they may transmit malaria in villages that had been free of sacharovl and the disease. The numbers of mosquitoes in late autumn dispersal flights is in direct proportion to the distance from the breeding sites. It was suggested that the proportion of females with fat body to be found in the autumn in any given place could be used as an indicator of the distance between the breeding source and the resting place where they were found, (citing Kligler & Mer, 1930).

In Syria, Sollman (1961a) studied the dispersal of sacharovl from its breeding places in the Rouge valley in the central western part of Syria, some 90 km from Aleppo. Within the valley and its west end, several natural springs were flowing into marshy areas. The development of a new irrigation project within the area led to drainage of most of the marshes, and enabled the cultivation of part of the area. It was expected that when the project is completed, the whole valley will be brought under cultivation and the vast breeding places suitable for anophelines, particularly sacharovl would no longer exist. During routine entomological surveys, it was decided to investigate the natural distribution pattern of sacharovl in relation to the distance of different villages from its breeding sites. In each of the selected villages, four rooms and four stables were searched by hand capture in the early mornings. The results were based on the mean of three surveys carried out in each village. The observations were carried out in June 1958 when the density of sacharovl was still high (the peak was in May). The results showed that: sacharovl frequented villages closer to the breeding sites at a higher density than the distant villages, provided that hosts are available. Villages situated at 0.5-1 km yielded 120-173 females of sacharovl/man-hour, while villages situated at 2-3 km from the same breeding source, yielded 4-7 females/man-hour. Catches made at two villages situated at 4.5 and 7 km respectively gave 1-2 females/man-hour, but none was caught in a village situated at 11 km from the breeding site. It was concluded that although sacharovl can disperse up to 7 km, its highest concentration is within one km from the breeding site.

1.5 Local spatial and seasonal distribution

In Spain, An. labranchiae used to be an important vector in the southeastern part of the country. Blazquez & Zulueta (1980) explained that unlike atroparvus which has a widespread distribution in Spain and Portugal, labranchiae was found only in an area of approximately 1000 km² in the provinces of Alicante and Murcia. It was the only member of the An. maculipennis complex present in this area except in its southern part in the vicinity of Cartagena, and in the north near Elche, where it was associated with atroparvus. The annual incidence of malaria in 1944 in the labranchiae area was 28 times greater than in the rest of the malarious area of Spain. This showed that labranchiae had been an important vector in Spain. DDT and HCH spraying applied in 1947 had an immediate effect on the prevalence of malaria and labranchiae, and by 1949 its larvae could be found in rice fields of San Fulgencio, in the centre of its distribution area. Entomological investigations were carried out by Blazquez & Zulueta (loc.cit.) covering this locality and other parts of the labranchiae area during September 1973, July 1978 and May-June 1979. The investigations covered 39 localities of which 12 were examined twice and three times. The number of houses, stables, cow-sheds, pigsties and other structures searched (in 132 man/hours) was 220, and the number of larval sites searched was 45 involving about 20 dips per breeding place examined. None of these surveys, nor the trapping carried out during one night by man-bait capture and light traps, yielded a single specimen of labranchiae. There was also a complete absence of atroparvus in places where it had been present previously in association with labranchiae. The only anopheline found was Anopheles algeriensis captured in animal shelters and by a light trap. These results led the authors to conclude that labranchiae has disappeared from the only area it occupied in Spain, thus reducing considerably the receptivity to malaria. The extensive searches made
during three separate years substantiate the claim that *labranchiae* has disappeared from Spain and from the Iberian Peninsula as a whole. This must have been due to the combined effect of residual house spraying, and the application of agricultural pesticides on a large scale. The discontinuation of rice cultivation in 1952, and improved drainage as well as changes in agricultural practices, must have also contributed to the disappearance of *labranchiae*. The fact remains that *atroparvus* is still found in most parts of its former area of distribution in Spain and Portugal seems to indicated that, unlike *labranchiae*, *atroparvus* is a species of long standing and well adapted to the conditions of the Iberian Peninsula.

In France, some records were reported on the distribution of members of the An. *maculipennis* complex. Rioux & Ruffié (1957) using larval chaetotaxy discovered the presence of *subalpinus* in Bas-Languedoc. Rioux, Sicart & Ruffié (1958) applying the cytotaxonomic method of Frizzi (1953) recorded the following species in the south of France:

- *subalpinus*: in the Toulouse region (Grenade-sur-Garonne).
- *atroparvus*: southwest of Toulouse.
- *maculipennis* s.s.: in the same area as above.

Later, Sicart, Rioux & Ruffié (1958) gave a full account of the cytogenetic identification of the three species in the Toulouse region, applied on larval samples collected from southwest of Toulouse and Goures Ducail at Grenade-sur-Garonne. Previously the authors identified *maculipennis* s.s. and *messeae* from this area, based on the character of egg ornamentation, but it was realized that *messeae* does not exist in the Toulouse region where it was probably replaced by *subalpinus*, a species which has a distribution range extending appreciably beyond the Mediterranean subregion. It was also pointed out that there is almost total resemblance between the eggs of *messeae* and *subalpinus*. The presence of *atroparvus* could help to clarify the question of the responsible vector that had been involved in the historical epidemics of malaria in the Haut-Languedoc.

As shown under 1.2 above, Cousserans, Salières & Tesson (1974) recorded *maculipennis* s.s. in the Montpellier area in addition to the already present *subalpinus*; the identification was based on the characters of the eggs, which were obtained from adults collected from shelters near the breeding sites.

Salières et al. (1978) identified the members of the An. *maculipennis* complex occurring in the area of Languedoc-Roussillon coastline during four summer seasons. The cytogenetic method could not be applied as this would need profound experience with the chromosomal arrangements of each species. Resort was, therefore, made to diagnosis based on the character of the antepalmate hair on segment IV and V in 4th instar larvae with the statistical analysis of data. The character of the egg was also considered. Three species were recognized: *maculipennis* s.s. (found only once in the region under study – see above), *subalpinus* (very abundant, the ornamentation of its eggs exhibited marked polymorphism), and *atroparvus* found only in the fourth season of observations.

Reference has already been made to the study of Pichot & Deruaz (1981) (see under 1.2 above) who recorded for the first time *maculipennis* s.s., and confirmed the presence of *messeae* in the Lyon region.

Suzzoni-Blatger & Sevin (1981) studied statistically the chaetotaxy of the larvae of *maculipennis* s.s., *atroparvus*, *subalpinus* and *messeae* which have been recorded in the Toulouse region. It was found that the characters of the larval population of *atroparvus* were not significantly different from those of the same species existing in Montpellier, France and Portugal but they greatly differed from those of *atroparvus* of Germany and England. While the *maculipennis* population was not significantly different from that of Montpellier, it was significantly different from that of Albany. The authors concluded that the larval chaetotaxy is a poor character for differentiating between members of the An. *maculipennis* complex, particularly when *maculipennis* s.s., *atroparvus* and *messeae* coexist.

In Italy, as has been shown under SECTION I, 1.2.1 (i) in document VBC/90.1-MAL/90.1, Coluzzi (1980) showed that recent entomological surveys demonstrated the absence of the main vectors An. labranchiae and An. sacharovi in certain areas. This has been attributed to environmental changes such as elimination of swampland areas, pollution of waters by industrial wastes, and contamination of breeding places with herbicides or agricultural pesticides. In some areas the Anopheles populations were even replaced by anthropophilic populations of Cx. pipiens. However, Anopheles populations are still present in all areas not affected by such environmental changes. High densities of labranchiae have been reported from some sectors in Lazio in Viterbo province, Toscana in Grosseto province, as well as Calabria, Sicily and Sardinia.

From a survey carried out in Latina province, Italy, during 1965-1968, Sacci, Scirrochi & Stella (1969) found that out of 13 Anopheles species previously recorded, only five were encountered, viz: maculipennis s.s., melanon, claviger, petragnani and plumbeus, all of which have a low degree of anthropophily. It seems that the main malaria vectors have been eradicated from all the province. Of 126 213 adult mosquitoes collected during the survey period, only 847 were anophelines, and the remaining were mostly Cx. pipiens which is increasing every year due to water pollution.

Further, Majori et al. (1970) studied the residual anopheline fauna in the Grosseto province, Italy. DDT house spraying which had been applied for many years was finally discontinued in 1966, not only because of the interruption of malaria transmission, but also in view of the appearance of vector resistance. Instead, oil larviciding was applied and proved to be effective not only on anophelines but also on culicines. During the larviciding campaign of 1969, a survey was carried out in the coastal areas of the province where malaria vectors had been present previously. The following species were recorded: claviger, algeriensis and maculipennis s.l., with melanon and messeae separated on the basis of egg morphology. The fact that the main vectors, labranchiae and sacharovi were not encountered during this survey in their characteristic breeding places indicates that their densities must have been greatly reduced, or the two species have been eradicated from the province. The authors observed a marked increase in melanon density associated with rice which was being grown on an experimental basis in the coastal areas of the province. If successful, rice cultivation will be extended, and the risk of labranchiae and sacharovi returning to the area was underlined. The authors also stressed the need for periodical monitoring of anopheline density, and at the same time applying oil larviciding which has given satisfactory control of residual anopheline fauna and other exophilic species. In fact, rice cultivation was introduced and extended in San Donato in the same province starting from 1975 and labranchiae became abundant breeding in rice fields as reported by Bettini et al. (1978) — see under 1.2 above.

In Sardinia, also shown above under 1.2, Marchi & Munstermann (1987) indicated that there has been a progressive increase in the breeding sites positive for An. labranchiae over the past 35 years.

In Sicily, as already mentioned under 1.2, D'Alessandro, Bruno Smiraglia & Lavagnino (1971) studied the biology of An. labranchiae. Although the species exists at sea level, large numbers were found at altitudes higher than 200 m. The studies were carried out in central and western parts of Sicily, since repeated searches showed the absence of anophelines in the eastern part of the island. The studies aimed at determining the seasonal distribution and the physiological age of labranchiae population. Anophelines were collected in domestic shelters (houses, stables etc.), and extradomestic sites (caves, bridges, hollow trees and animal burrows). The specimens were brought alive to the laboratory where they were processed for identification of the species, examination of the spermatheca, and determination of the physiological age by Polovodova's technique (in Detinova, 1962). In Sicily, the warm dry season lasts six months, from May to October. During this period the temperature varies between 20 and 35°C. Winter lasts about four months, from December to March, when the temperature is about 10°C and rarely falls below 0°C. Under these conditions the period of seasonal prevalence of labranchiae is April-September, and its hibernation period is October-March. Accordingly, the results were presented for the two contrasting periods as shown in the following:

(a) Period of winter rest: Results of dissection of samples of labranchiae females collected from all types of shelters at several localities during the period
October 1966-March 1967, are presented in Table 1, and data of gonadaactivity recorded in samples of the same species classified according to the type of shelter are presented in Table 2.

The observations showed that males of *labranchiae* disappeared in November, and 90% of a total of 686 females dissected were inseminated. As shown in Table 1, the number of females with fat body, particularly the non-gonaoactive, gradually increased reaching a maximum in December-January, which are the months with shortest day-light. From Table 2, it seems that hibernating females of *labranchiae* preferred to rest in natural or extradomestic shelters. The data also provided evidence that hibernation was incomplete since the following categories of females were encountered:

- non-gonaoactive females with fat body which could represent truly hibernating females;
- non-gonaoactive females with little or no fat body, some of which had blood in their guts;
- gonaoactive females with fat body
- gonaoactive females without fat body;
- parous females existed in winter (October-March) although their proportion did not exceed 22.3% (153/686). Most of the 153 females were 1-parous and only a few were 2-parous. In November, there were only three parous females determined as 2-parous, of which one had a small amount of fat body. In February, of 29 females dissected there were 27 determined as 1-parous, of which eight had fat body and only two as 2-parous which did not have fat body. It appears that the parous females behaved physiologically just as the nulliparous in that their hibernation is incomplete, i.e., it is possible that some females can break their diapause and become gonaoactive, but their survival seems to be curtailed.

(b) Period of seasonal prevalence:

- when the larvae of *labranchiae* made its first appearance in April 1967, no adult females could be found in shelters searched;
- the first abundant catches of adult females were obtained in the second half of May. A high density was recorded in a stable situated at about 50 m from the breeding places in the river Tato, and this represented the typical ecological habitat of *labranchiae* in Sicily:
  - almost all the females were inseminated;
  - the density peak appeared in August;
  - in summer females of *labranchiae* prefer to rest in domestic shelters.

In their conclusions, the authors pointed out that *labranchiae* is still present in some limited areas of Sicily, where the habitat has not been altered, and continues to rest indoors and outdoors. However, it is anticipated that in the near future, with the environmental changes arising from construction of dams and land reclamation under way, as well as the increase of high-yield crops and the progressive reduction of the human population due to migration, the density of *labranchiae* population will further decrease. [This contrasts with the situation of the same species in Sardinia—see above].

Cephalù & Lavagnino (1978) who reviewed research studies on anophelines remarked that *labranchiae* in the island exhibits incomplete hibernation. Its females appear with fat body starting from October. They are capable of laying eggs even in cold months when the temperature is low.

In Yugoslavia, several entomological surveys have been carried out in different areas since 1974 until recently, as part of arbovirus mosquito studies, and also to determine the distribution and relative abundance of the potential malaria vectors mainly in former malaria endemic areas, in view of the increasing number of imported cases. The results of these surveys were progressively published principally by Dr Z. Adamović of the Institute of Medical Research, Belgrade. In these surveys mosquitoes were collected alive exclusively from indoor resting shelters in human dwellings and animal houses. Some or nearly all members of the An. maculipennis complex have been recorded depending on the
Table 1. Records of gonad activity and the presence of fat bodies in the nulliparous and parous females, October 1966 - March 1967

<table>
<thead>
<tr>
<th>Month</th>
<th>Temp. °C in domestic shelters</th>
<th>Total number females dissected</th>
<th>Nulliparous</th>
<th>Parous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gonoactive with fat</td>
<td>Non-gonoactive with fat</td>
</tr>
<tr>
<td>October</td>
<td>a 29</td>
<td>12</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>b 95</td>
<td>58</td>
<td>-</td>
<td>13</td>
</tr>
<tr>
<td>November</td>
<td>a 23</td>
<td>18</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>b 34</td>
<td>21</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>December</td>
<td>a 6</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>b 137</td>
<td>133</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>January</td>
<td>a 27</td>
<td>23</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>b 241</td>
<td>213</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>February</td>
<td>18-21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a -</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b 72</td>
<td>43</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>March</td>
<td>a 15</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>b 17</td>
<td>9</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

a = below 200 m from sea level.

b = above 200 m from sea level.
Table 2. Observations made on female *A. L. Labranchiae* found in domestic or natural shelters.

<table>
<thead>
<tr>
<th>Month</th>
<th>Nulliparous</th>
<th></th>
<th>Parous</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number females</td>
<td>Gonoactive</td>
<td>Non-gonoactive</td>
<td>Number females</td>
</tr>
<tr>
<td>October</td>
<td>37</td>
<td>3</td>
<td>34</td>
<td>22</td>
</tr>
<tr>
<td>November</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>December</td>
<td>55</td>
<td>1</td>
<td>54</td>
<td>3</td>
</tr>
<tr>
<td>January</td>
<td>25</td>
<td>22</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>February</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>March</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>130</td>
<td>35</td>
<td>95</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Month</th>
<th>Natural shelters</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>33</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>November</td>
<td>31</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>December</td>
<td>83</td>
<td>2</td>
<td>81</td>
</tr>
<tr>
<td>January</td>
<td>211</td>
<td>24</td>
<td>187</td>
</tr>
<tr>
<td>February</td>
<td>43</td>
<td>34</td>
<td>9</td>
</tr>
<tr>
<td>March</td>
<td>2</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>493</td>
<td>90</td>
<td>313</td>
</tr>
</tbody>
</table>
area; their identification was based on the characters of the eggs which were raised from
the adult females collected. Anopheles species other than the members of the An.
maculipennis complex were: superpictus (considered as a potential vector), claviger,
byrrhanus, plusbeus, and algeriensis in some areas. The general features that can be drawn
from these surveys are summarized as follows:

- atroparvus predominates in areas of alkaline and saline soils due to relatively high
concentrations of dissolved salts in stagnant and slowly flowing waters, as in Potišje of
the Pannonian plain, south Baria and west Bačka.

- messae was the most predominant anopheline species in the alluvial plains of the
great rivers of the Danube and Sava and the lower reaches of Velika Morava river in
Serbia. It was rare in the hilly area of Pocerina with a notable exception as it was
abundantly present at one village, Vukošić. Although it seems that messae breeds
characteristically in great inland valleys with large marshes and swamps, an extensive
swamp with a marginal belt of dense submergent, floating and emergent vegetation was seen
near Vukošić. The proximity of a typical breeding site could explain the abundance of
messa adults at this hilly village. On the other hand, the population density of
messa was very low in South Serbia and Macedonia compared with that found in the
lowlands of the great rivers of the Danube and Sava. Along the rivers Vardar and Crna
Reka, there had been large swamps which were drained after World War II, and a large area
of fertile soil has been reclaimed for agriculture. The elimination of many swamps may be
one of the possible factors influencing the decrease in abundance of messae in the
lowland of South Serbia and Macedonia.

- atroparvus and messae were extremely rare in the lowlands of Macedonia where hot
and dry climate seem to be the limiting factors for the two species.

- maculipennis s.s. was most abundant in Procerina, Serbia, southeast Serbia and east
Macedonia.

- sacharovi was recorded resting indoors much more frequently than any other member of
the An. maculipennis complex at sites close to the area of saline and alkaline soils in
east Macedonia. It was also collected indoors associated with subalpinus at Zogajsko
Blato in Montenegro where marshy plains of brackish water existed.

- while subalpinus was recorded in five areas, melanoon was identified (only one
female) for the first time from south Serbia. Repeating and extending the search for this
species was suggested.

- labranchiae was encountered only in one area: Ravni Kotari in northern Dalmatia
which has a Mediterranean climate, where subalpinus, sacharovi and superpictus were also
recorded.

- the following species of the An. maculipennis complex are considered important
potential vectors in Yugoslavia: maculipennis s.s., atroparvus, messae, labranchiae and
sacharovi.

For the distribution of superpictus see under 2. below.

For detailed information on the distribution and the relative abundance of anopheline
species in different areas of Yugoslavia, interested readers should consult the following
(1983).

Early observations in Yugoslavia by Guelmino (1951) provided useful information on the
hibernation and the associating physiological changes in certain species of the
An. maculipennis (hitherto considered varieties) viz: typicus (= maculipennis s.s.),
messae and atroparvus. The observations were conducted at a village where messae
constituted 63% of the anopheline population, and another village where typicus formed
91%. As atroparvus represented only 2.2 and 1.1% of the anopheline population in the two
villages respectively, the physiological study of this species during hibernation could
not be conducted. During summer, the three species congregate in stables having similar
attraction to the host and to favourable physical conditions. With the approach of the
winter, while typicus and atroparvus remain in warm stables where domestic animals are kept, and where they rest throughout the winter, messeae changes its habitat and flies to a cold shelter. The hibernation of messeae in cold shelters is the most pronounced ecological feature which distinguishes it from typicus and atroparvus and is due to physiological adaptation of messeae for spending the winter at a low temperature. The first preparation of messeae for hibernation is this change of the resting habitat which occurs at the end of August or the beginning of September. Despite the fact that messeae abandons warm stables in favour of a cold shelter, it continues to feed up to the middle of November. The bloodmeals are digested slowly, as shown by the unchanged appearance of the blood within the alimentary canal for a period of many days. This species continues to oviposit until the end of September when oviposition comes to an end, although the mean outdoor temperature is 15.5°C. Follicular development, however, continues after the cessation of oviposition and does not subside until the end of October. Females caught during this period appeared to have active ovaries, though the eggs were not completely formed. Although the follicular activity appeared to be proceeding, the follicles themselves were apparently at a stage of incipient involution. The formation of adipose tissues in the abdominal cavity of messeae begins early, at the time when oviposition is being discontinued, although ovarian activity has not completely subsided, as was demonstrated by finding follicles at different stages of development. With further formation of fat body, a parallel involutive process takes place within the follicle, until the ovaries finally lose their resemblance to active gonads. From the beginning of November until the end of February messeae is to be found in a state of complete hibernation i.e., it remains passive, does not react to light, and cannot be roused, even by touch, from its winter lethargy. From the beginning of March, the hibernation comes to an end, when messeae migrates in large numbers from its cold quarters to stables where animals are kept. At that time, the stored fat has nearly disappeared, and the females begin to feed on blood, and the ovaries become reactivated. The first oviposition of females of messeae which were brought to the laboratory occurred on 17 March, when the mean outdoor temperature was 10.7°C. While messeae hibernates in a state of lethargy, typicus maintains a certain degree of activity, as was shown by its periodical feeding on blood and its active sensory reactions. The differences in physiology and behaviour of messeae and typicus during hibernation was attributed to microclimatic factors, particularly the temperature of their habitat. While messeae prepares for hibernation in September, typicus does so at the beginning of October; its physiological adaptation for hibernation differs somewhat from that of messeae. The blood feeding of typicus continues during November-December, but ceases completely in January. The number of blood-fed females decreases proportionally with the fall in the outdoor temperature. Thus, the feeding activity of typicus is directly influenced by the microclimatic condition of its habitat, particularly the temperature. Besides which the process of digestion of the blood is very slow; fresh blood in the ventricles did not change in colour for 8-10 days or even longer. In typicus oviposition ceases when the mean outdoor temperature is 11.5°C, and ovarian development is completely suspended at 5-7°C. The reproductive functions cease completely by the end of October; the last oviposition was seen in the laboratory on 14 October. The winter temperature in the stables where typicus rests is higher by 5-6°C or more than the outdoor temperature, depending on the structure of the stable and the number of cattle within. Thus, the cessation of ovulation and the arrest of the follicular development occur in the two species merely at different times, but the temperature conditions are approximately the same. The process of formation of adipose tissue which in messeae is completed during the prehibernation period, is prolonged in typicus until the coldest days. By periodical feeding on blood, typicus replenishes its reserves of fat which have become exhausted by its more active metabolism; an activity caused by the higher temperature within the stables. It is known that the metabolism of the insect is dependent upon the internal temperature which is proportional to the temperature of the environment. During November-December, the temperature in many stables is about 10-15°C, a level which is above the limits necessary for the mosquito nutritional activities. The number of typicus with adipose tissue progressively increases throughout the initial period of the winter up to January, at the end of December about 80% of the mosquitoes could be seen without a reserve of fat. In January when the temperature within the stables falls below the limits necessary for mosquito feeding activities, typicus passes from a state of semi-hibernation to complete hibernation, and its decreased need for energy is supplied by endogenous caloric material from the adipose tissue. The outdoor temperature begins to rise progressively until it reaches 6°C in the second half of February. By that time the stored fat in typicus, which is less than in messeae, is almost exhausted; bloodmeals are, therefore, recommenced and follicular activity begins
afresh. Oviposition starts at the beginning of March, when the mean outdoor temperature is 7.5°C.

In Romania, as mentioned under 1.2 above Duport et al. (1974) showed that the potential vectors of malaria are: *atroparvus, messea, maculipennis s.s.*, and *sacharovi*. They explained that in 1961, the residual house spraying was discontinued in about half of the endemic area that entered the consolidation phase of the malaria eradication programme. The absence of indigenous malaria cases led to discontinuation of the spraying from 1965 in the whole country. The year 1961 marked the appearance of dieldrin resistance in the anophelines and from 1964-1965 moderate DDT resistance was recorded in members of the *An. maculipennis* complex. During the 4-5 years that elapsed after the cessation of spraying, the anopheline density increased but not in a regular manner; the collective system in agriculture and in domestic animal raising changed the concentration sites of mosquitoes, thus represented the technique of zooprophylaxis. In 1973, anophelines were rarely seen in human dwellings, unlike the situation that existed before the introduction of house spraying. This does not represent a modification in mosquito behaviour, but it is a consequence of improved living conditions of villagers. They generally undertake control of mosquitoes by individual application of insecticides, and prevention of mosquito entry into their houses. The change in anopheline species composition was observed at Enisala locality, Tulcea district due to the diminution of *sacharovi* population density. For example, the proportion of this species dropped from 96.8% in 1961 to 2.3% in 1962, to zero in 1963. This was not an isolated phenomenon, as this species has not been encountered on the Romanian littoral starting from 1963-1964.

Bilbí et al. (1978) carried out an investigation to update the knowledge of potential vectors in the previously endemic areas of the Danube plain and Dobrudja, since the number of malaria imported cases in Romania has been increasing and could lead to re-introduction of malaria transmission. The investigation was carried out during 1976-1977 covering 48 localities in seven districts. The choice of the localities was based on the presence of a high incidence of malaria and the predominance of its vectors before the introduction of malaria eradication. The investigation comprised recording social and environmental conditions, location of the breeding sites, indoor resting collection, determination of species composition and carrying out insecticide susceptibility tests. Eggs were raised from adult females caught alive for identification of members of the *An. maculipennis* complex. The results showed a general decrease in the density of the former vectors. This was attributed to social and environmental changes, of which reference was made:

(a) residual house spraying carried out during the malaria eradication campaign (1949-1960) resulted in a general reduction of the endophilic species notably *sacharovi* and *atroparvus*;

(b) almost complete elimination of many breeding sites due to extension of agriculture and improvement of water management;

(c) the disappearance of some feeding sources due to the numerical decrease of draft animals as a result of mechanized agriculture;

(e) the high mortality among mosquitoes due to the use of insecticides particularly organophosphorus compounds in agriculture and in individual farms.

The quantitative reduction in anopheline fauna led to changes in species composition of the former four major vectors: *sacharovi, atroparvus, messea* and *maculipennis s.s.* The essential changes have been: the disappearance of *sacharovi*, the considerable reduction in *atroparvus* density, and the prevalence of *messea*. The situation of these former vectors was shown as follows:

- *sacharovi* had been the major vector of malaria in restricted areas along the Black Sea shores. Its presence in this area of Romania was regarded as the extreme north adaptation limits of the Mediterranean climate. It was responsible for severe epidemic waves in Constanta and Tulcea districts where the prevalence of malaria was often as high as 100%. The species has been under continuous monitoring until its disappearance was recorded in 1963 (citing Duport et al., 1974 – as shown above). The present investigation carried out during 1976-1977 confirmed the absence of *sacharovi* from several localities and areas it previously occupied.
- *atroparvus* in the past had been an important vector of malaria through its presence in most of the localities of the endemic areas. It used to be quite widespread in the country and its breeding occurred in sites with high water salinity, but its bionomics and vectorial efficiency varied from one region to another. Now, it has decreased in numbers in many localities. Of 32 localities investigated, in only six did *atroparvus* constitute over 50% of the anophelines collected. Comparative observations in 20 localities where information on the anopheline species composition 20 years previously was available showed that the proportion of *atroparvus* decreased in 13 localities. In certain areas this reduction was quite marked, but in others it was less clear.

- *messeae* has now become the predominant species in the whole area investigated. In 26 out of 32 localities examined this species constituted over 50% of the anophelines collected and in 15 localities it even exceeded 80%. Previous data showed that this species was much less widespread. In 17 out of 20 localities examined, *messeae* showed a marked numerical increase. The previous house spraying of the malaria eradication campaign affected the anthropophilic indoor resting *sacharovi* and *atroparvus* particularly in Dobrudja, but had little effect on *messeae* by virtue of its exophilic tendencies allowing it to escape the action of the insecticide.

- *maculipennis* s.s. is the fourth former vector occurring especially in hilly areas. Its role in malaria transmission in the past was considered of low order of magnitude. Its prevalence now has not been changed except in some localities where its proportion decreased.

In conclusion, the authors considered that with the present situation of the former vectors, the chances for re-introduction of malaria in the Danube plain and Dobrudja has been considerably reduced. This has been particularly due to the disappearance of *sacharovi* and to the quantitative reduction of *atroparvus*. However, the prevalence of the latter species in certain localities, and the presence of very high densities of *messeae* in some areas should be kept in mind, although the latter species in the past had a very low sporozoite rate (0.07%).

In Bulgaria, Dimitrov et al. (1960, 1962) indicated that from early studies the following members of the An. *maculipennis* complex were recorded in the country: *maculipennis* s.s. (=*typicus*), and *sacharovi*. Other anopheline species encountered were: *superpictus, sergentii, hyrcanus* (pseudopictus), *claviger* and *marteri*. Of all these species, only *maculipennis* s.s. and *superpictus* were playing an important role in malaria transmission. It was not possible to determine the role of the other species. The species composition of anopheline fauna on the Bulgarian littoral of the Danube had not been exactly determined before 1956. Following the convention to undertake malaria eradication on both sides of the Danube, the authors carried out systematic surveys covering 28 localities on the Bulgarian side of the Danube during 1956–1958. Species of the An. *maculipennis* complex were found to consist of: *messeae* (63.1%), *typicus* (32.1%), *melanoon* (1.8%), and *atroparvus* (0.3%) – this was a collection from a stable at a single locality). It was observed that *messeae* clearly predominated in the eastern half of the study area, while in localities situated 18–20 km from the Danube bank populations of *typicus* exclusively existed. In conclusion, the authors anticipated that the progressive drying and cultivation of land in the Danube plain, which started in 1944, would lead to changes in the breeding conditions of anophelines, and consequently the eradication of malaria from the Bulgarian Danube littoral in a few years.

In the USSR, information on the distribution and vectorial importance of members of the An. *maculipennis* complex was presented by Artemiev (1980) as follows:

- *maculipennis* s.s.: Before eradication of malaria in the USSR, *maculipennis* s.s. was the major vector of malaria in Georgia, Armenia, mountainous areas of Azerbaijan and Dagestan, and in certain localities of the northern Caucasus. At present, *maculipennis* s.s. acts as a potential vector. Its vectorial efficiency is probably lower than that of *sacharovi, superpictus* and *pulcherrimus*.

- *melanoon*: This species is found only in humid areas in the plains which have warm winters. Formerly, it was a malaria vector in some areas of Lenkoran lowland, Abkhazia, and Kabards. Its vectorial efficiency was less than that of *maculipennis* and *sacharovi*.
- messeae: This species is widely distributed in the USSR. In the east, it reaches the northwestern Manchuria and Blagoveshchensk. The southern boundaries pass through Central Kazakhstan, the lower reaches of the Emba river, and the foothill areas of northern Caucasus. Females of messeae hibernate in cold shelters far away from their hosts. Hibernation of messeae is complete and the females never take bloodmeals in winter. In the Moscow region, diapausing (prehibernating) females are first observed in July, and by mid-September they constitute a majority of the anopheline population. In the spring, females of messeae migrate out of shelters of different types at different times and occasionally migration may last 1-2 months. Near Moscow, the migration from shelters may vary in different years from mid-April to mid-May, usually occurring at a mean daily temperature of 4-8°C. In summer, messeae females begin to fly and feed when the temperature rises to 7°C; the upper limit of the activity is at 25-30°C. At 25°C, their biting frequency is high, but at 30°C it is nil; the upper limit for the life of the adults is 35°C. The optimal temperature in resting places in summer is 19-21°C. This is a hygrophilic species, and it begins to avoid dry resting places when the air humidity is below 65%. Water losses in messeae occur more rapidly than in any other anopheline species, and this appears to be the main factor preventing its southward spread. An. messeae was the species which stimulated the appearance of the term "anophelism without malaria". The high densities of this species in northern Europe and Siberia were not compatible with the absence or low incidence of malaria; the main cause of this phenomenon being the low temperature. In the latitude of Vologda, it was estimated that in one out of three or four years the temperature is sufficiently high to allow the completion of one sporogonic cycle. In the latitude of Moscow, a cold summer occurs once every three or four years when malaria transmission becomes impossible. Thus, adverse temperature conditions solely make messeae an inefficient vector. However, the susceptibility of messeae to malaria parasites, its density, degree of contact with man and survival rates are all sufficient characteristics that would allow malaria transmission to occur. This had been repeatedly witnessed in the past, when large outbreaks of malaria occurred in the middle belt of Russia or Siberia in certain years.

- atroparvus: The northern boundaries of this Atlantic species is roughly a straight line from Kaliningrad in the west to Astrakhan in the east. This species is particularly abundant in the southern Ukraine and northern Caucasus. It also extends southward to Alder and Gudermes, and is common in the Crimea. Unlike messeae, atroparvus hibernates in relatively warm quarters in areas of mild winters. During hibernation, the temperature usually varies from 3 to 9°C, and only occasionally falls to zero. Hibernating females exhaust their fat reserve rapidly and are obliged to take bloodmeals from man or animals during winter, but the ovaries do not develop, as the bloodmeal is used for formation of fat. As temperature rises, atroparvus emerges from hibernation. Hibernation in atroparvus tends to be more prolonged than in messeae under the same conditions. In the past, biting of atroparvus during hibernation was considered at times as of great epidemiological importance, since it favoured the formation of foci of transmission within houses. Malaria cases were seen where the proportion of infected specimens among hibernating females was as high as 20-30%. However, early heating of the rooms, though favoured the cessation of hibernation, it caused the death of diapausing females and thereby elimination of microfoci. Because of its distribution in regions of temperate climate, atroparvus had not been an active vector in the past. Nevertheless, it had been responsible for stable malaria foci in certain areas of the Ukraine, the Crimea and northern Caucasus during the last century.

- sacharovi: This is the most southerly and the most thermophilic species of the An. maculipennis complex in the USSR. It is the dominant species in the plains of Transcaucasia and Dagestan, and is abundantly present in northern areas of Turkmenia and Tadjikistan, and it also occurs in Kazakhstan. It penetrates into northern Kazakhstan up to 46° N. There had been numerous records of this species in the past in southern areas of Turkmenia, Uzbekistan and Tadjikistan, but these are no longer valid. If this species had been present in the hotter regions, it probably disappeared after the institution of malaria control measures. The Central Asian and Transcaucasian forms of sacharovi differ appreciably in their ecological requirements, and there has been evidence reported by V.N. Stegnii that the arrangements of the polytene chromosomes of the two species are different. Obviously, Artemieiev presented his notes before the final designation of the

1. The two forms have now been separated; the name An. martinius has been reinstated as the valid name for the taxon existing in Central Asia, and the name An. sacharovi has been retained for the Transcaucasian taxon - see Stegnii (1976), White (1978) and Stegnii (1982) in pp. 27, 29 and 31 respectively in VOLUME I, under 1.1.2.
two taxa as independent species. As he expected this designation to materialize, he reviewed the bionomics of sacharovi in the USSR on the basis of two separate forms: the Central Asian (now = martini) and the Transcaucasian (now = sacharovi). Therefore, the summary of his review shown below should be interpreted according to the new designation of two independent taxa. In Central Asia, where winters are relatively cold, hibernation follows the same pattern as that of messeae, i.e., the females rest in cold shelters and do not feed. In Azerbaijan, the hibernating habit is similar to that of atroparvus, hence the possibility of man to contract the infection during winter should not be excluded. In both Central Asia and Transcaucasus, hibernation usually ends in February, but females entering hibernation appear earlier in Central Asia, usually in September. In Transcaucusus, where the climate is mild, hibernation begins 1-1 1/2 months later. Normally, the form of Central Asia has 5-6 generations, while that of Transcaucusus has 6-7 generations. In Azerbaijan, the seasonal prevalence varies from one area to another. Where temporary pools predominate and dry up by mid summer, the density peak occurs in June, after which the density declines progressively reaching near zero by the end of the summer. In areas having numerous permanent breeding places and hot climate, the density remains very high throughout the summer and the first half of the autumn. Very large numbers of diapausing females come to hibernate in houses. A third seasonal density peak may still be seen usually in cool areas of the foothills where many suitable breeding sites occur. Although enormous numbers of anophelines are seen at the beginning of hibernation, very few of them survive the winter. An. sacharovi is considered the most dangerous vector in the USSR, with Transcaucasian form showing a much higher vectorial efficiency than the Central Asian form. The main reasons are: the high temperature extending the season of anopheline activity and consequently the transmission season is prolonged; the persistence of a high anopheline densities from year to year; and the endophilic habit that results in a high degree of contact with man. All these characteristics are much less manifested in the Central Asian populations.

In Greece, Hadjinicolau & Metzios (1973a) while presenting the results of their investigation on An. sacharovi in Thermopylae village in Lamia plain provided some information on the anopheline fauna of this area. Lamia plain, which is situated at 190-250 km northwest of Athens, was formerly an area with a high degree of malaria endemicity. The vector species were maculipennis s.s. and sacharovi of the An. maculipennis complex, as well as superpictus, but sacharovi was considered the most important vector. Other Anopheles species considered as non-vectors were: byrcanus, claviger, algeriensis, plumbeus and marteri. The Lamia plain was subjected to intensive DDT house spraying from 1946 to 1959, after which period no residual insecticide has been applied for malaria control. Prior to DDT spraying, sacharovi was the most predominant species in the lower part of Lamia plain, while maculipennis s.s. and superpictus were represented by proportions of 4-17% and 1-8% of the total vector species collected respectively. During 1968-1970, catches showed that the most predominant species was sacharovi standing as the potential vector of malaria in Greece. After World War II, a lot of drainage work has been done in the Lamia plain, particularly in freshwater marshy areas, and thousands of hectares have been reclaimed for agriculture. This resulted in the virtual disappearance of maculipennis from the area. In addition, a stream that flowed from the hills, through the plain, to the sea has been diverted for irrigation, and no other breeding places suitable for superpictus exist in that part of the plain.

In Turkey, some information was provided by Postiglione, Tabanli & Ramsdale (1973) on the distribution of members of the An. maculipennis complex related to the breeding habitat, as shown under 1.2 above. From further information provided by the same authors, maculipennis s.s. is the most widely distributed in Turkey; its area extends from the west coast to the eastern highlands. An. subalpinus has been recorded from the Black Sea coast, European Turkey, the Marmara Region and the central Anatolian plateau. Both maculipennis s.s. and subalpinus were present in high densities in the formerly malarious plains of Biga, Cannakale province as well as in certain areas in northern Turkey. However, their role in malaria transmission in many places was obscured by the simultaneous presence of sacharovi or superpictus or both. An. sacharovi is undoubtedly the major vector of malaria in Turkey where its area of distribution extends from the western and southern coastal plains and valleys, to the hot southeastern provinces bordering Syria and Iraq. It also extends to the central plateau, but it is absent from the eastern and northeastern highlands, and from the greater part of the Black Sea area. It is the dominant species in all areas which are still malarious or where malaria resurgence has occurred. All three species of the An. maculipennis complex hibernate as
adults in Turkey. In general, human dwellings are sufficiently heated during winter, thus they are too hot and dry for mosquito survival. In contrast, stables and other animal shelters are cold when they are empty during the day, but at night after the animals enter them, they become warm and sufficiently humid to permit mosquitoes to feed and survive throughout the winter. On the other hand, sacharovi females were found in complete hibernation under subzero temperature conditions in natural shelters. Collection of mosquitoes from day-time resting shelters and by baited-net traps in Turkey, indicated that females emerging from hibernation were short-lived, and relatively few females survived until the appearance of the adults of the first summer generation. Adults are invariably scarce during April-May, and the build-up of densities varies between places rather than between species. The regions of greatest malaria receptivity are those with irrigated cultivation where the extent of breeding depends on agricultural practices. In these areas, high adult densities are not observed until July, with peaks usually appearing in August and early September.

Ramsdale & Haas (1978) provided further information on the hibernation of members of the An. maculipennis complex (including sacharovi) as well as superpictus in Turkey. Diapausing (prehibernating) females probably start to appear in August or early September. Thus, the autumn populations are composed of two groups: older, non-diapausing females, whose larval development was completed during the summer, and younger, diapausing females which will eventually give rise to the summer generations of the following year. Diapausing females may take one or more bloodmeals after emergence, but appear as the season becomes progressively cooler. Most females pass the winter in stables, where the cool, humid environment is more favourable to their survival than the desiccating conditions in human dwellings, and where continued feeding on animals leads to depletion of any sporozoites that may have been formed. Though the possibility exists, winter transmission has never been recorded in Turkey, hence of little epidemiological significance. Reactivation of mosquitoes during the spring occurs at temperatures below the threshold of the malaria parasites, or under conditions in which the sporogonic cycle is greatly prolonged. Therefore, it is improbable that newly reactivated mosquitoes are able to transmit malaria in the spring, though they may acquire an infection at that time, and some can survive to a potentially dangerous age as was established in the USSR (citing Detinova, 1962). However, reactivation occurs during the unstable conditions of the spring, which are characterized by intermittent warm, cold and stormy periods. Observations in Turkey indicated that most mosquitoes have a rather short reactivated life, with very few surviving long enough to become infective.

Clarke (1982) in an unpublished report to WHO gave more specific information on the seasonal distribution of sacharovi in Çukurova plains, south of Adana. During the winter in the low-lying and warmer area of Çukurova, sacharovi does not enter true hibernation. Intermittent feeding does not lead to ovarian development and the females remain in gonotrophic dissociation throughout the colder months. The first male specimens of sacharovi which indicate the emergence of the first adult generation were collected on 25, 27 and 29 March 1980, 1981 and 1982 respectively. Two peaks of sacharovi were observed. The first occurred in May-June following a marked increase in density in early April, then the density rose again forming the second peak in September-October. Thereafter, a decline was observed until the lower winter densities were reached by December. Two peaks of malaria cases occurred approximately one month after sacharovi peaks. The low densities observed in August were not due to malaria vector control but to the effect of the aerial insecticide application on cotton plantations from mid-July to mid-September. Cotton crops represented 81% of crop cultivation in the lower Seyhan irrigation scheme in 1981.

Kasap (1987) summarized the results of his observations on the effect of photoperiod on the development of sacharovi in controlled insectary and field conditions in Turkey. Both laboratory experiments and field observations showed that long days increased the biting rates of sacharovi females, and shortened the developmental period of the immature stages and the length of the first gonotrophic cycle, hence a rapid population increase under conditions of long days. In the field, oviposition ceased when the photoperiod became shorter than 10 hours and the temperature was less than 18°C, but this did not occur in the laboratory at 8 hours photoperiod, because the temperature was maintained at 25 ± 2°C. It was concluded that decreasing temperature coupled with decreasing day length appeared to be important factors in initiating hibernation of the adult females.

1. Written also Chukurova.
Recently, Mlimoğlu, Kasap & Kasap (1958) studied the relationship between the seasonal density of *sacharovi* and the malaria incidence in Chukurova area. The observations were carried out during the breeding season of *sacharovi*, i.e., February to November. The density of *sacharovi* started to increase from February reaching a peak in May, followed by another peak in September. A second peak was observed in July, but was not as high as the other two peaks. Malaria cases increased at least one or two months after the seasonal peaks of the *sacharovi* population.

In Morocco, Guy (1959a) wrote a comprehensive memoire on the taxonomy of Moroccan anophelines with notes on their biology and distribution. Further, Guy (1959b) presented the available information on the distribution of anopheline species existing in the country and their relation to malaria transmission. *An. labranchiae*, the ubiquitous malaria vector in North Africa, was found to be widely distributed in the Mediterranean and Atlantic coastal areas in Morocco. Its inland distribution extends from Rif to Moyen Atlas. Its southern limit is demarcated by the northern slopes of the Haut Atlas, but it was recorded further south in some oases such as Foum-Zguid and Tagounit (citing Gaud, 1953). It is essentially a species of the maritime plains as it forms 95% of the anopheline population on the Atlantic littoral extending from Tanger to Mazagan [south of Casablanca]. Two observations illustrate the close relationship between malaria prevalence and *labranchiae*. The first was the considerable increase in spleen indices from May to October which coincided with the great frequency of the population of this species. Secondly, examination of the map of the endemic zones of malaria laid down by Dr J. Gaud in 1952 showed that there was a zone in the region of Rabat-Meknès-Fez, where the spleen indices were well over 25%, and this was the principal zone of *labranchiae*.

Guy & Holstein (1968) reported the results of further studies on the anopheline fauna of the Maghreb. With regard to *labranchiae*, its southern limit was in the Biskra region in east Algeria, slightly above 35°N latitude. Cautious entomological searches provided evidence that *labranchiae* was present in Ferkane and Ain Medla in the department of Annaba, slightly above 34°N latitude. Nevertheless, it was found in Morocco slightly south of 31°N latitude in Ouazzazate province. Its presence in Algeria was connected with autochthonous cases of malaria grouped in much denser foci than those usually seen in arid zones where this species does not exist. Some observations stimulated the authors to investigate the conditions of hibernation of *labranchiae* as the major vector of malaria in North Africa. During the fourth quarter of 1965, observations carried out on the Atlantic and Mediterranean littorals, showed that the population of *labranchiae* consisted of two fractions: one fraction was formed by females passing through partial hibernation as evidenced by the presence of fat body, fresh blood and cessation of ovarian development, and the other was formed of gonoactive females. In the Larache region, south of Tanger on the Atlantic coast, the proportion of females having fat body and the ovaries in Christopher's stages I and II, increased from 10% to 50% as the distance from the ocean to the interior increased, while the proportion around the Mediterranean coast was only 3-7%. Out of 434 females of *labranchiae* dissected during the last quarter of 1965, 43.9% were gonoactive. During the first quarter of 1966, December 1966 and the first quarter 1967, samples of *labranchiae* females collected from the same Larache region were dissected. The proportion of females with fat body did not exceed 7% of 142 dissected in March 1966, and there was a high proportion of females with ovarian stages III-V in the whole period of observation. During the winter of 1967-1968, all the females collected were gonoactive and none had fat body, despite the fact that winter was very severe. It was, therefore, presumed that some factors other than those of the temperature and humidity may induce true hibernation. To determine the epidemiological implications of the presence of active populations of *labranchiae* on the Moroccan littoral during the whole year, an infant blood survey was systematically conducted in the same area of the entomological investigation. Of 181 blood slides, four were positive: 3 *P. vivax* and 1 *P. falciparum*. The infection was contracted at the earliest in November 1986. However, the investigation led the authors to conclude that these cases were related to transplacental transmission.

Benmansour, Laaziri & Mouki (1972) summarized the records of anophelines in Morocco and discussed the geographical, climatological, economical and operational factors influencing species distribution. They also pointed to observations carried out by Holstein in 1966, indicating that *labranchiae* is the principal vector of malaria in Morocco. Its spatial and seasonal distribution, longevity, degree of contact with man are characteristics which ensure maintenance of malaria transmission.
In Algeria, Holstein et al. (1970) further listed and mapped the distribution of anopheline species with special reference to the fauna of the Sahara. This information was needed for extension of the malaria eradication programme to the south of Algeria. The entomological studies that were initiated by the Sergent brothers at the beginning of the century (Sergent & Parrot, 1961) were pursued up to recent years by adding new information on anopheline distribution in the country. Information given here concerns only labranchiae, while species other than those of the An. maculipennis complex are shown under paragraphs 2 and 4 below. The distribution of labranchiae was shown in 1968 to be in the extreme south of Annaba department in the pre-Saharan zone. The present surveys showed that larvae were found south of Laghouat, thus extending its existence beyond the precipitation curve of 200 mm per annum. Reference was made to two previous records of labranchiae in the Hoggar region of the Sahara at Silet and Abalessa. These have been doubted since they were based on single female specimens obtained by night capture. The authors considered that these specimens must have been imported through passive transportation. To confirm this, they searched for the possible existence of a relict population in Hoggar, but were unable to find adult specimens or suitable larval breeding sites.

Ramsdale & Zulueta (1983) who studied the implications of construction of a trans-Saharan highway [see subsection (ii) 2 below], underlined that labranchiae is the most important malaria vector in the western Mediterranean and is still responsible for foci of P. vivax near the Algerian coast. They agreed with Holstein et al. (1970) that the most southerly limit of labranchiae is Laghouat on the southern slope of the Atlas, and that the presence of specimens of this species previously recorded at Silet and Abalessa must have been due to passive transportation. To confirm this, they searched for the possible existence of a relict population in Hoggar, but were unable to find adult specimens or suitable larval breeding sites.

In Libya, labranchiae was recorded from Tripolitania which seems to be the easternmost limit of distribution in North Africa (see under 1.2 above), as indicated by Macdonald (1982).

In Tunisia, long before the malaria eradication programme was established, Juinier (1959) showed that labranchiae is widely distributed in all northern coastal areas, and extends also to the south in two lines: one passing from Tabarka to Neftzoua, and the other extending from Mahdia to Neftzoua passing through Kairouan and Sbeitla. In his assignment report, Werndorfer (1973) indicated that based on the pre-eradication survey which was carried out in 1957, labranchiae has been considered as the principal vector in the northern and central regions of Tunisia, while sergeinti acts as the main vector in the southern region.

In Israel, Saliternik (1957) reviewed the historical observations on the seasonal distribution of sacharovi which are useful to recapitulate in view of the recent reappearance of this species (see under 1.2 above). On hibernation, the behaviour of sacharovi was similar to that observed in Turkey. Due to mild winters in Israel, no true hibernation was found among local anopheline populations. At the beginning of winter (October or November), males of sacharovi disappear and fertilized females begin to store fat and enter a state of semi-hibernation. According to Mer (1931) hibernation begins in October at a temperature which is usually higher than that of the spring when their activity commences. The females which eventually enter into hibernation do not emerge from pupae with stored fat body, but accumulate it prior to hibernation. The tendency to accumulate fat body occurs when pupa develop at low autumnal temperatures. The length of time that the fat body remains in the female depends upon the winter temperatures. If the winter is milder than usual, the female may obtain some bloodmeals during hibernation, develop its eggs earlier and even occasionally oviposit during the winter. On seasonal prevalence, data were presented to show the monthly temperature and the percentage of sacharovi of the total annual catch. At temperatures of 12.4, 13.2 and 15.2°C in January, February and March respectively, the percentages showed that sacharovi may reappear in large numbers a month earlier than usual, but if the winter was cold with heavy rains, the reappearance of sacharovi may be delayed by one month. The data also showed that sacharovi has two peaks: April-July and October-December, with a falling density between July and September. An increase in the numbers of adults was observed in areas where breeding continues throughout the summer. Changes in the physical conditions of localized breeding sites may permit continued breeding, thereby the density of sacharovi adults increases during July-September.
Pener & Kitron (1985a & b) reported on the reappearance of *sacharovi* in Israel (see also under 1.2 above). *An. sacharovi* which used to be one of the most important vectors of malaria in Israel, was not found from 1960 to 1969. It was subsequently rediscovered in the Golan heights by Ben-Dov (1971 - see under 1.2 above). It is now found in Hulla valley and along the west coast of the Sea of Galilee. In 1983, it was found 30 times constituting 14% of the total number of larvae collected. Also in 1983, it was found, for the first time since the 1950's, in the Haifa administrative region. On the extent of *sacharovi* distribution, the authors showed that it also exists in the Jordan valley and eastwards. In the Tiberias region, *superpictus* and *sergentii* have always been present, until *sacharovi* joined them, as shown by surveys made in 1981-1983. Regarding the seasonal distribution, the seasonal changes in prevalence of anopheline species seems to be related more to changes in their total [relative] frequencies than to actual changes in their seasonal pattern. One possible exception may be *sacharovi*, which in the past had two peaks: one from April to June, and one in October-December with a decrease in summer (see above). These two peaks were associated with two peaks of malaria cases in early summer (June) and late autumn (November). Based on the relative frequency of *sacharovi* larvae among all anopheline species, the monthly distribution of its larvae in recent years (1974-1984) shows a clear peak in March. Subsequently, the frequency becomes low from April to July, and then rises in August for the late summer peak, and remains relatively high until November (no data are available for the winter season, December-February). More observations are needed to determine accurately the seasonal pattern of *sacharovi*. This would show whether this change will persist, and whether it is part of the adaptation of this species to the reinvansion of its former habitats, which have since become much modified through agricultural and urban development.

In Lebanon, Gramiccia (1953) indicated that in coastal regions, *sacharovi* predominates at the beginning of the summer, but gradually is partly replaced by *superpictus*, then followed by *hyrcanus* and rarely *sergentii*. In villages of hilly regions, *superpictus* (and rarely *sacharovi*) is followed by *claviger* in the autumn and the beginning of the winter, particularly in villages with an abundance of wells (cisterns) where it can complete its development all year round.

In Syria, Abdel-Malek (1958) showed the spatial distribution of *sacharovi* as indicated from larval surveys conducted from March 1953 to December 1954 (see under 1.2 above). On the seasonal prevalence, the density of *sacharovi* adults increased gradually from May onwards reaching a peak in October. [This contrasts with *sacharovi* in Israel where it was shown that its density declines late in the summer - see above]. Abdel-Malek further showed that from November until February, *sacharovi* females were found inside human habitation and stables in a state of hibernation.

1.6 Resting behaviour & 1.7 Biting behaviour

Information on the resting and biting behaviour of members of the *An. maculipennis* complex in the Mediterranean basin is available from a limited number of countries.

It is useful to recapitulate the early knowledge on the two aspects from the book of Senevet & Andarelli (1956) as a basic background.

- *maculipennis* s.s.: This species is easily deviated to animals. Despite being zoophilic, it may, nevertheless, bite man and transmit malaria accidentally.

- *messeae*: It is a vector of malaria in certain regions, but in general, it should not be considered as an important vector because it is also zoophilic. It rests in animal shelters that have few air currents, e.g., cattle sheds, horse stables and pig shelters.

- *melanooon*: It is a zoophilic species; it plays a minor role in malaria transmission. In the rice cultivation area in the Valence region, Italy, it used to exist in abundance, but there was no malaria, unlike the situation in [formerly] rice growing areas in Portugal where *atroparvus* was the most predominant vector.

- *subalpinus*: Its role in malaria transmission is less than that of *atroparvus* or *labranchiae*; it rests in animal shelters and less frequently in human habitation.

- *labranchiae*: Its principal host is man, but it can deviate to animals when man is unavailable. It is an important vector of malaria in the Mediterranean basin. It is strictly endophilic, but it exhibits exophilic tendencies under certain conditions.
atroParvus: It is a domestic species with undistinguished zoophilic tendencies. While it was not considered a vector of malaria in Italy, it was the main vector in Portugal, Spain and north of the Alps.

sacharovi: It voluntarily bites man and rests in human habitation, but it can readily bite animals.

In Sicily, Italy, Cefalù, Oddo & Sacci (1961) carried out studies on the bionomics of the labranchiae population during 1959-1960 and early 1961 in the Roccamena area, Palermo province, where DDT house spraying was discontinued for three years. Among these studies were observations on the resting behaviour of this species by direct collections of samples from domestic and extradomestic (natural) shelters (caves, crevices and the under sides of small bridges), and by mark/release/recapture experiments as shown in the following:

Observations on the distribution and the physiological state of labranchiae in domestic and extradomestic shelters for which the following data were presented:

Table 3(a) Data of collections made in 1959 & 1960

<table>
<thead>
<tr>
<th>Site of collection</th>
<th>Total collected</th>
<th>Unfed</th>
<th>With fresh blood &amp; females with mature ovaries combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>4446</td>
<td>28.1</td>
<td>71.8</td>
</tr>
<tr>
<td>Extradomestic</td>
<td>1303</td>
<td>59.9</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 3(b) Data of collections made in September 1959

<table>
<thead>
<tr>
<th>Site of collection</th>
<th>Total collected</th>
<th>Unfed</th>
<th>Physiological state X</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Unfed</td>
</tr>
<tr>
<td>Domestic</td>
<td>256</td>
<td>44.8</td>
<td>30.4</td>
</tr>
<tr>
<td>Extradomestic</td>
<td>148</td>
<td>52.3</td>
<td>17.8</td>
</tr>
</tbody>
</table>

The above data clearly show that a high proportion of unfed females was recorded in natural shelters. Newly emerged females seem to prefer to rest as a first step near the breeding sites. The data of Table 3(a) also shows that the proportion of fed + gravid females in natural shelters was 40% versus 72% in domestic shelters. The gravid females found resting in natural shelters probably was composed of the following fractions:

(a) those coming to rest in outdoor shelters after feeding on blood until the gonotrophic cycle is completed;

(b) and those which completed the gonotrophic cycle in domestic shelters and left them before the oviposition time was due.

Assuming that the duration of the gonotrophic cycle in summer is 48 hours, theoretically there should be an equal proportion of fed and gravid females, if no movement occurs. As shown in Table 3(b), the proportion of females with fresh blood was greater than that of the gravid in domestic shelters, but the situation was the opposite in the extradomestic shelters. This supports the suspicion that a proportion of females leaves the domestic shelters before the completion of the gonotrophic cycle, but the data were not sufficient to draw firm conclusions. The outstanding problem is to know whether the females which completed the entire gonotrophic cycle in natural shelters had fed outside or obtained their bloodmeal indoors and left after feeding. Precipitin tests were run on bloodmeal smears of labranchiae females collected resting in domestic and natural shelters. Of 436 smears from domestic shelters 9.9% were positive for man, 80.9% for bovid, 4.4% for other domestic animals, and 4.8% undetermined. Of 54 smears from natural shelters, 3.7% were positive for man, 64.8% for bovid, 11.2% for other domestic animals, and 20.3% undetermined. The high percentage of bovid-positive smears was not considered

1. The authors' summary has been expanded by translating parts of the text through the kind cooperation of Dr F. Oddo, former WHO Malariaologist.
significant from the standpoint of feeding preference, as it only reflects the situation in the study area where cattle represented the most abundant host available for *Anopheles*. The smears which were positive for man came from houses or mixed dwellings, while the two man-positive smears from natural shelters came from a cave. These observations indicate that *labranchiae* females rest in the same shelter in which they had fed, as in the case of domestic shelters, and also those captured in natural shelters must have fed on cattle outside during summer, i.e., exophagic.

Mark/release/recapture experiments: Since *labranchiae* is a difficult species to colonize in the laboratory because of its eurygamy, the release experiments were made with wild-caught females with two different strains: methylene blue for those collected from domestic shelters, and eosin for those collected from natural shelters. Laboratory observations on stained mosquitoes showed that they survived well and their colours remained for a sufficient time. The distribution of marked *labranchiae* females in the two types of shelters and the recapture rates are shown in Table 4.1

<table>
<thead>
<tr>
<th>Released</th>
<th>Recaptured</th>
<th>Source</th>
<th>Colour</th>
<th>Total</th>
<th>% Unfed</th>
<th>Recapture Site</th>
<th>Colour</th>
<th>Total</th>
<th>% recap site</th>
<th>Colour</th>
<th>Total</th>
<th>% recap site</th>
<th>Unmarked</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>Blue</td>
<td>2205</td>
<td>22.6</td>
<td></td>
<td></td>
<td>Domestic</td>
<td>Blue</td>
<td>20</td>
<td>0.9</td>
<td>9</td>
<td>1.24</td>
<td></td>
<td>934</td>
<td>963</td>
</tr>
<tr>
<td>Natural</td>
<td>Red</td>
<td>722</td>
<td>34.4</td>
<td></td>
<td></td>
<td>Natural</td>
<td>Red</td>
<td>13</td>
<td>0.58</td>
<td>6</td>
<td>0.83</td>
<td></td>
<td>345</td>
<td>364</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2927</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>33</td>
<td>1.49</td>
<td>15</td>
<td>2.07</td>
<td></td>
<td>1270</td>
<td>1327</td>
</tr>
</tbody>
</table>

tabular text

Although the recapture rates were low, the experiments rendered useful indications of the resting behaviour of *labranchiae* in relation to domestic and natural shelters. The females that originated from domestic shelters (marked blue) were recaptured in both domestic and natural shelters. Likewise, the females that originated from natural shelters (marked red) were recaptured in both domestic and natural shelters. This indicates that the females of *labranchiae* are indifferent with regard to selection of a certain type of shelter. Their choice of the resting shelter is probably influenced by external factors, i.e., the availability and proximity of one type of shelter or another. The data also show that the recapture rate was higher in mosquitoes that originated from natural shelters (marked red). This was probably due to the presence of a high proportion of younger mosquitoes which virtually lived longer. This may be supported by the fact that the natural shelters were in close proximity of the breeding sites, and a larger proportion originally caught from natural shelters were unfed. It was concluded that the experiment provided evidence of facultative exophily in *labranchiae* in Sicily, in the sense of Senior-White (1954)2 and Gillies (1956)2. This behaviour is exhibited by the population as a whole and it is likely that the assumption of the existence of two distinct population variants: one is endophilic and the other exophilic can be ruled out. The authors further considered the assumption that the facultative exophily is due to selection pressure of DDT as improbable. It is more plausible to assume that the species has behaved like this since its origin and its behaviour has not been lost despite its long association with man and domestic animals. From a practical standpoint, the importance of the outdoor resting behaviour of *labranchiae* lies in the fact that it protected this species from being eradicated by DDT spraying. Hence, *labranchiae* will be able to invade the domestic environment again, after the discontinuation of mosquito control by insecticides.

1. Permission to reproduce Tables 3a & b and Table 4 was granted by Dr F. Oddo and Parassitologia from the article of Cefalu, Oddo & Saccà (1961).
In the USSR, Artemiev (1980) described maculipennis s.s. as endophilic and resting in human dwellings and stables. It feeds on man both indoors and outdoors. The proportion of females with human bloodmeals depends on the number of cattle in a given farm. An. melanoon is an exophilic or semi-exophilic species preferring to rest on vegetation, banks of canals or other humid outside shelters. In Lankoran lowland, it was recorded from human dwellings, but only in small numbers. It feeds on man indoors and outdoors, but has marked preference for cattle. An. messae is an endophilic species to a considerable extent as it was found in large numbers in stables, barns and cellars as well as in human dwellings. It usually feeds on cattle, although feeding on man is not uncommon. An. atroparvus is an endophilic species which feeds both indoors and outdoors. It prefers to feed on bovids, but readily feeds on man. An. sacharovi in Transcaucasus is endophilic as it has not been observed resting in nature, whereas the Central Asian form (= An. martinius) exhibits a certain degree of exophily. It feeds on man but would also feed on cattle when available.

In Turkey, Postiglione, Tabanli & Ramsdale (1973) described the resting behaviour of maculipennis s.s., subalpinus and sacharovi. Houses or stables, or both, are often unoccupied, but whether occupied or not, the darker stables offer more attractive resting sites than do houses, and usually harbour large densities. An. sacharovi is most common in houses but, like the other two species is much more abundant in stables. Exit-traps fitted to un sprayed premises captured females of all three species in various physiological conditions. This confirmed early observations in Greece prior to house spraying that the females exhibit a marked tendency to leave their indoor shelters during the night, irrespective of the degree of their ovarian development. Exit-traps fitted to DDT sprayed premises showed that all three species were quickly irritated by DDT, which despite causing only low mortality, forced them to rest in outdoor-resting shelters. However, outdoor-resting was not solely due to DDT irritability as large numbers of females could be found in outdoor-resting shelters in the absence of house spraying. The number of females found in outdoor-resting shelters tends to reflect the number of easily searched shelters rather than the actual magnitude of outdoor-resting. This was found to vary from one place to another, depending on the relative attractiveness and availability of indoor and outdoor shelters, the concentrations of hosts during the night, and other local conditions. The types of outdoor-resting sites were similar for each of the three species, and included hollows and cavities under earth banks, under bridges, caves, rock cavities, hollow trees and shaded stacks of beehives.

On the biting behaviour, the authors pointed to observations elsewhere indicating that sacharovi differs markedly from maculipennis s.s. and subalpinus in its degree of anthropophily. Precipitin tests run on bloodmeal smears of sacharovi collected from different areas of its distribution showed that this species has a greater degree of anthropophily (citing Bruce-Chwatt, Garrett-Jones & Weitz, 1966). Baited-net traps operated in un sprayed and sprayed villages, as well as analysis of bloodmeal smears of sacharovi collected from different biotopes in Turkey confirmed this feeding preference. The actual amount of feeding on man which takes place in Turkey depends on the local conditions that may provide protection for people from mosquito bites. Numerous domestic animals are stalled in each village at night, and in summer they are usually dispersed outside amongst houses. In cooler regions, people sleep indoors throughout the year, often on an upper storey, but in other regions they sleep outside in summer, on the flat roofs of their houses, or on upper storey balconies, or at ground level, thus the relative availability to mosquitoes is not constant. Bed-nets are almost universally used. However, all people, whether sleeping indoors or outdoors, are most vulnerable to mosquito bites during the evening before they retire, and when they are sitting in the open in their villages. During harvest, villagers often sleep in the fields, where the same protection is not offered as that of the presence of concentrations of animals in villages. Even when they return to their villages to sleep, they start working in the fields at dawn and continue until dusk, and they often rest in the fields during the heat of the day. Observations in different parts of Turkey showed that people sleeping in the fields were heavily attacked by sacharovi, and to a much lesser extent by maculipennis s.s., and that in a sheltered situation, sacharovi was a persistent biter during the day. The important crops in Turkey are cotton, rice and sunflower, and these are harvested during late August and September. By this time, mosquito populations have already reached or passed their peak densities and contained an increasing proportion of older, more epidemiologically dangerous females. Thus in most rural areas, the period when people are most exposed to mosquito bites coincides with the period when the probability of receiving an infective bite is highest.
In Morocco, Guy (1963) described *labranchiae* as an endophilic mosquito as it is found abundantly in the morning in human habitations and animal shelters. Also in Morocco Saccià & Guy (1960) using irritability tests in the laboratory and conducting field observations demonstrated that *labranchiae* evaded DDT sprayed surfaces. The irritability of *labranchiae* was much more pronounced than the natural movement observed in untreated control batches of the same species. Despite this pronounced irritability of *labranchiae* to DDT, no inferences could be made as to the implications of these findings to the antimalaria campaign. As these results were of a preliminary nature, it was suggested that more profound studies should be conducted with the following aims:

- to elaborate the development of a more accurate method for measuring the irritability of mosquitoes on a standardized basis;
- to determine the levels at which the DDT irritability would exert an influence on malaria transmission;
- to determine whether the irritability is a result of selection pressure or whether it pre-exists in normal populations.

No information is available to indicate that such studies have been undertaken. However, indirect evidence that neither irritability to DDT nor the natural facultative exophily of *labranchiae* had any operational implications, comes from the fact that the malaria eradication programme in countries of North Africa successfully completed the attack phase and advanced to the maintenance phase. There is no evidence that the few residual foci of transmission are due to refractory behaviour of *labranchiae*.

In Algeria, Collignon (1959) in his studies on the biology of the anophelines in the Alger region, observed the resting behaviour of *labranchiae* in many localities in the northern part of the country. This species is always attracted to places where man or domestic animals abound. In general, premises exclusively occupied by animals are much more attractive than those utilized by man. Stables constitute a main resting shelter for this species, as they contain humid dark corners protected from air currents. The presence of *labranchiae* in indoor resting shelters during day-time is not an obligatory constant biological character. The urge for feeding may at times drive the females to feed on hosts available in nature. The turnover of the *labranchiae* population at night causes a considerable number of females to wander in nature, eventually leading to exophily. Observations were made at a site where a small reed shed situated between a breeding place and dwellings. The site was located under trees where some bovids were stalled. The site escaped the attention of personnel undertaking an imagocidal programme applied at that time. The number of *labranchiae* females caught was similar to that obtained from the same site one year previously. It was, therefore, deduced that the large number of females that persist in nature do not come in contact with treated premises, or that the majority of these are distantly situated in nature, thus escaping the action of the insecticide. In summary, the character of endophily or partial exophily of *labranchiae* females seems to depend on the exterior conditions whether favourable or unfavourable for their turnover. The females resort to human habitations and their accessible premises when these satisfy their need for feeding and resting.

No newer information could be traced on the resting and biting behaviour of *labranchiae* in its area of distribution in North Africa.

In Israel, Saliternik (1957) referred to early observations in the Huleh swamp area, whereby the greatest concentration of *sacharovi* was located in houses and bedouin tents during May-July. However, the habits of the human population may influence the localized density of mosquitoes. For example, the frequent folding and transporting of the tents during summer, and the smoke from fires during the cool nights of the autumn were among the factors that reduced the number of mosquitoes in the tents (citing Kligler & Mer (1932). On the resting sites, *sacharovi* prefers to cling to the horizontal surfaces that do not transmit the heat well, such as the underside of beds, wooden shelves and tables, while a few rest on walls and spider webs. On very hot, dry days *sacharovi* was sometimes found on the lower portions of the walls near the floors. In summer, *sacharovi* was mostly concentrated in stables and barns, while in winter it was found in attics, store rooms and cellars. In the open bedouin tents, *sacharovi* females were easily found in the early morning hours before the winds began to disturb them.
In Syria, Abdel-Malek (1958) observed sacharovi resting in human dwellings, stables and other animal shelters. Its adults were caught while resting on ceilings or roofs. Spider webs hanging from roofs in mixed dwellings (man and animals) and stables in villages were the preferred resting sites. Adults of sacharovi were usually associated with adults of superpictus in its resting sites. Females of sacharovi were never caught outside resting shelters.

Muir (1982) (unpublished report to WHO) while on a mission to Syria to participate in technical discussions on a possible change of malathion used by the malaria control programme, collected data of house-resting densities and the blood digestion stages of sacharovi recorded by the programme from sprayed and unsprayed villages in the Hama area. During July-August 1980, the density of sacharovi in the unsprayed village was in the range of 32.5-43.4/room, while in the malathion sprayed village, it was 1-2.4/room. The fed (F): half-gravid (HG): gravid ratio (G) in the unsprayed village was 1.44:0.77:1 during July-August. Assuming that the duration of the gonotrophic cycle during that period was 2.5-3 days, this ratio gives a preliminary indication that sacharovi in the Hama area is endophilic. In the sprayed village, there was a large deficit in the gravid proportion; the F:HG:G ratio was 62:7:1, as would be expected from the effect of malathion to which sacharovi was still susceptible.

Further, Sadek (1984) (unpublished report to WHO), while conducting observations in Syria to assess the effectiveness of permethrin house spraying, recorded the blood digestion stages of sacharovi sampled by pyrethrum spray collection (PSC) and by exit-trap collection (ETC) in sprayed and unsprayed villages in the Quneitra area, south-west of Damascus during September-October 1983. The density of sacharovi in the unsprayed village was 41.8-71.6/room during September, and the F:G ratio was 0.86-1.04:1, giving a preliminary indication that sacharovi in Quneitra area is also endophilic. During the same period, the density in the sprayed village was 0.7 and 6.7/room 8 and 22 days after permethrin spraying and F:G ratio was 3:0 and 4.8:1 respectively. The sample of October in the unsprayed village unexpectedly showed F:G ratio of 1.56:1 with a density of 24.4/room versus 1.5:1 with a density of 6.8/room in the sprayed village. No explanation was offered as to the high F:G ratio in the unsprayed village whether some special circumstances influenced the exodus of a proportion of females before completing the gonotrophic cycle. The number of females obtained from exit trap collection was too small to allow inferences to be made as windy and cold conditions prevailed during the latter part of the observations.

On the biting and resting behaviour of sacharovi some information is available from observations made in Syria previously during DDT spraying in 1968 and recently in an area under permethrin spraying in 1985. Zahar (1974) (citing unpublished data by Onorì & Zahar, 1968) pointed out that confirmation of the presence of DDT resistance in sacharovi in the Ghab area, Syria was obtained during July-August 1968, and at the same time entomological/parasitological observations were carried out to determine the operational implications of DDT resistance. At the time of susceptibility testing, sprayed surfaces showed extensive disturbance from replastering and whitewashing. Females of sacharovi were collected from disturbed and apparently sprayed premises in fair densities and at different stages of the gonotrophic cycle, mostly on unsprayable surfaces, though a few were collected from sprayed walls. The number of indigenous malaria cases increased progressively after the first DDT spraying round of 1968. Exit window trap observations showed that sacharovi leaves the house mainly in the unfed and gravid states. The mean trap mortality was 18% indicating little effect of DDT spraying, the mean biting density per man per night was 8 indoors by direct bait capture and 15 by baited nets outdoors. Most of the people in the Ghab area sleep outdoors in summer and sacharovi enters houses during the early hours of the morning after feeding outdoors. Thus, sacharovi seems to be largely endophilic in the Ghab area.

Zahar (loc.cit.) further pointed to the area occurring at the junction of the Khabur and Tigris rivers on the borders of Iraq, Syria and Turkey where swampy areas provide sacharovi with suitable breeding places. The biting of people sleeping outside during summer and the suspected outdoor resting of sacharovi were thought to be responsible for the persistence of malaria transmission in this ecologically homogeneous border area despite DDT spraying (citing Zulueta, unpublished report to WHO, 1967). Larval susceptibility tests carried out in October 1965 at Derik in El Hasseke province showed that sacharovi was still susceptible to DDT.
Recently, Eshghy (1986) while working in Syria made observations in the same border area of northeast Syria under permethrin spraying covering six villages during 29 September-2 October 1985. In each village, 10-12 rooms were searched for adults with negative results. Bait capture on four men conducted at one village for three hours commencing at sunset yielded only two superpictus. Surveys of breeding places at three villages yielded several larvae of sacharovi and superpictus. During seasonal crop cultivation in some areas near breeding places, the inhabitants sleep outdoors from June to September. Most of the biting occurs outdoors during the transmission season and leads to persistence of transmission in this border area. Eshghy further explained that it cannot be stated with certainty whether a proportion of the populations of these vectors enters the sprayed premises, or seeks resting shelters outdoors, thus evading contact with the sprayed premises.

1.8 Sampling mosquitoes in flight

Very limited information is available from the geographical area under review.

In Morocco, Baillie-Choumara (1973a) reported the results of a small scale trial for assessing the efficiency of the CDC light trap (of Sudia & Chamberlain, 1962) as a mosquito sampling tool in comparison with conventional sampling methods. The trial was carried out at Larache-Sheishat (in the North Atlantic plains with sub-humid climate) where An. labranchiae predominated. The houses selected had a ceiling of well-constructed hard board wood under the roof. The houses were relatively closed without gaps between the walls and roofs, but many gaps existed at the level of the doors and window shutters. The animal shelters were situated close to houses, and their construction was poor. They were formed of three walls joined by a roof, all made of reeds. They were used as a shelter of newly born or sick animals, but most of the livestock are kept in the open around houses surrounded by thorny enclosures. The trial was conducted over three nights (13, 14 and 15 May 1968) shortly after the spring explosion of mosquito populations. A CDC light trap which was operated with 4.5 volts torch batteries was placed in a bed-room, another trap in the nearest animal shelter, and a third trap in the open outside. Another set of CDC traps was modified by providing each with 12 volts battery and an ultraviolet (UV) light source. These modified traps were placed in the same sites, but after a few days following the operation of the normal traps. Each morning the bags of the light traps were emptied, and the residual fauna (= mosquitoes remaining in the same room as the trap) was collected by hand capture. Besides which, hand capture was made towards 1700 h in three rooms and three stables having the same conditions as those of the light traps. For comparison, direct man-bait capture and man-baited nets were utilized. Each method of capture was performed in the same site for three consecutive days with the exception of the UV trap which was operated for two days. The material collected was identified as to species including culicine mosquitoes. Females of labranchiae were classified according to the blood digestion stages, and the parous rate was determined on the fraction of the sample eligible for dissection by the technique of the ovarian tracheoles of Detinova (1962). Bloodmeal smears for precipitin testing were prepared from a certain number of females of labranchiae that were collected by the light traps. The conclusions drawn from this trial were as follows:

- The CDC light traps gave a good yield of Culicidae present in a locality in northern Morocco.

- The CDC light trap operated by torch batteries yielded a large number of labranchiae when placed in a fairly closed room.

- CDC/UV light trap operated by 12 volts battery collected higher numbers of labranchiae since it has a more powerful suction, but its mechanism was cumbersome, bulky, and fragile, liable to break down frequently.

- The majority of females sampled by the light traps was unfed, nearly similar to the sample collected by man-bait capture.

- The species composition of the fauna of a room without light trap that was sampled in the afternoon (1700 h) was analogous to that of the residual fauna sampled in the morning after the operation of the light trap; only labranchiae was the species present, with its engorged females forming 95% in the bed-rooms and 93% in the animal shelters.
- The proportion of engorged females in the residual fauna collected in the morning after the operation of the light traps was similar to that obtained from rooms without traps.

- Although the proportion of engorged females collected by the light traps was small, it rendered useful information on the origin of bloodmeals. The results of precipitin tests run on bloodmeals of labranchiae collected by the light trap was nearly similar to those of the residual fauna. Altogether the samples showed that a low proportion had fed on man (1-2%) and a very large proportion (89-93%) had fed on bovids. In the samples derived from the bed-rooms where no light traps were operated, the bovids remained the most frequent host (66%), but the proportion that had fed on man was much higher (25%) than in samples of the residual fauna or the light traps. It seems that the high zoophily of labranchiae caught by the traps in bed-rooms would support the assumption that the presence of the CDC light trap artificially augments the entry of the females that had fed outside on animals.

- The parous rates in samples of labranchiae collected by CDC or UV indoors whether in human or animal shelters were not significantly different (88% and 100% respectively) indicating that the samples were taken from a homogenous population. These rates also did not differ significantly from those recorded in samples collected by other methods (man-bait capture, residual fauna in human and animal shelters. In contrast, the parous rates of females sampled by CDC and UV light traps placed outside were much higher than those recorded in samples of man-bait capture (respectively 91% and 96% versus 74% from man-bait capture).

As a final conclusion, the author recommended the use of light traps for sampling labranchiae populations in Morocco as an efficient complement to the conventional sampling methods. Light traps may also be useful for sampling this species in other countries of the Mediterranean Basin. It was also suggested that assessing the efficiency of the light traps to sample populations of other anophelines under similar conditions should be tried.

Bailly-Choumara (1973b) further reported the results of a more comprehensive trial in Morocco involving eight sampling methods. These methods were:

1. Hand capture in human dwellings and animal shelters. When the mosquito density was low (1-20 females per room), the collector spent on an average five minutes per room.

2. Man-bait capture: This capture extended from sunset to sunrise employing 4 collector-baits indoors and a similar number outdoors.

3. Man-baited nets: One man slept under a bed-net, the lower edge of which was partially elevated, and engorged mosquitoes were collected in the morning. This method was applied only outdoors, and essentially tested in the stations of labranchiae.

4. CDC light trap: This was as described above, one trap was suspended from the ceiling of a bed-room where some people slept and another trap was placed in an animal shelter, and a third placed outdoors between houses.

5. CDC/UV light trap: As mentioned above, a CDC trap was modified to provide ultraviolet light. This trap was occasionally used in dwellings, stables, but often outside houses.

6. Sheet trap: This method consisted of collection of mosquitoes with an aspirator from a white screen made of a cloth sheet suspended vertically and illuminated by reflection of a 200 watts opaque bulb. This method necessitated the presence of a collector permanently, unlike the CDC light trap. It was always used outside, between the breeding places and the village.

7. Collection from outside resting shelters: This was done in certain localities by sweeping vegetation with a net. Also hand capture was made in one locality where a culvert existed near breeding places. It was also done in large earthenware pots serving public baths. At one locality, the only outside resting places were those among rocks at the sides of a river.
Several villages were selected as capture stations representing different geographical/ecological regions of Morocco. Most observations were carried out once monthly over a period of 1-2 years, except in remote stations where the observations had to be carried out on consecutive days. The selection of the stations in the rural zone of Morocco was based on the anopheline fauna, the presence of permanent breeding places, and proximity of malaria foci. The various regions, their bioclimatic substrata and the selected stations were as follows:

<table>
<thead>
<tr>
<th>Region</th>
<th>Bioclimatic substratum</th>
<th>Selected stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rif Occidental, Mediterranean coast</td>
<td>Mediterranean, temperate climate, sub-humid in winter</td>
<td>Tétouan, Merja (= swamp) of Smir river: This area situated near Gibraltar strait which is exposed to strong winds that often reduced mosquito yields. Merja had rich densities of <em>labranchiae</em> &amp; 2 <em>Aedes</em> spp.</td>
</tr>
<tr>
<td>North Atlantic plains</td>
<td>as above</td>
<td>Larache, Merja Sheishat: The predominant species were <em>labranchiae</em> and <em>Culex theileri</em>.</td>
</tr>
<tr>
<td>North Atlantic plains</td>
<td>semi-arid</td>
<td>Sidi Yahia of Rharb, Merja Poka: Culicines abundant; <em>labranchiae</em> maximum density at beginning of spring. Despite low density in summer, malaria endemity high.</td>
</tr>
<tr>
<td>Interior medium plains</td>
<td>Arid with temperate winter</td>
<td>Marrakech, Souk des Oudayas: Predominant species were: <em>sergentii</em> and <em>hispaniola</em> and was one of the rare stations of <em>Anopheles ziemmmani</em>; <em>labranchiae</em> density was lower than in the above stations, but station represented active malaria focus.</td>
</tr>
<tr>
<td>Oriental Morocco</td>
<td>Semi-arid with temperate winter</td>
<td>Berkane, Merja Boubker: <em>sergentii</em> and <em>labranchiae</em> predominated; region had small residual foci of malaria.</td>
</tr>
<tr>
<td>Interior south</td>
<td>Saharan with temperate winter</td>
<td>Foum Zguid, Mrimima river: a sub-desertic region where d’ta’aa and multicolour predominated.</td>
</tr>
</tbody>
</table>

The results of the different capture methods were discussed with the data tabulated and graphically presented for each species (anophelines and culicines) and station. For *labranchiae*, a summary of the results follows:

- Larache station: Hand capture gave a mean of 67 females/room in human dwellings and 27/animal shelter. Man-bait-capture indoors gave a mean biting rate of 31/man/night and a maximum of 166/man/night. The normal CDC light trap placed in a bed-room yielded 5- and 10-fold higher numbers of females than man-bait capture under the same conditions. The UV trap operated over three nights during the period of high density caught 20-fold more females than man-bait capture. Under the condition of poor construction of animal shelters, the CDC and UV light traps respectively yielded 7-fold and 3-fold less females than in bed-rooms, despite the zoophily of *labranchiae* as evidenced by the results of precipitin tests. Man-bait-capture outdoors gave a mean biting rate of 24 and a maximum of 101 bites/man/night, while man-baited nets outdoors gave 2-fold less bites/man/night. The CDC and UV light traps placed outdoors gave comparable yields to that of man-bait capture.

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outdoors under the same conditions, but yielded 10-fold less mosquitoes than the indoor traps. The yield of the sheet trap was poor and the Malaise trap was negative. It was concluded that the CDC and UV traps attracted much higher numbers of *labranchiae* females; their good performance, however, was seen only in well closed indoor shelters.

- Sidi Yahia and Marrakech stations: In these two localities, *labranchiae* existed under a more dry atmosphere which is less favourable for its survival. Its density was low, but it was still playing a good role in malaria transmission. The trend of the yield by different capture methods was similar to that observed at Larache; the best performance was obtained by the CDC and UV light traps in human habitation.

- Berkane station: This station provided results which were not concordant with the above mentioned stations. In this area of oriental Morocco, the stables being well constructed, gave a density of more than 1000 *labranchiae* females/stable by hand capture. Nevertheless, the light traps placed in these stables gave a much lower yield (maximum 12/trap/night) similar to those placed in bed-rooms of adjacent houses. An attempt was made to explain this inconsistency. Doubts about the functioning of the light traps were ruled out, since the same traps in stables caught a large number of *sergentii* (maximum 152/trap/night), despite the fact that its density in the stables was much lower than that of *labranchiae*. It was assumed that *labranchiae* during the visit to the station in mid-September was possibly in a state of prehibernation, hence not susceptible to attraction to light, while *sergentii* was at its maximum autumnal activity. Collection of a sample of *labranchiae* females by hand capture from a stable showed that 90% were bloodfed and 10% were gravids. Upon dissection, fresh blood was found but no traces of fat body were observed. The parous rate was about 63%. Apart from the deficit in the gravid proportion, there was no evidence favouring the commencement of prehibernation. This was the only instance where the light traps gave a poor yield despite the presence of a high density of *labranchiae* in the stable, a case which remains inexplicable.

- Tétouan station: This station is situated in a touristic region which has been regularly treated with DDT house spraying in addition to the use of space-sprays which were applied during the period of observations. Very high biting rates of *labranchiae* were recorded reaching a maximum of 112 bites/man/night indoors and 89 bites/man/night outdoors which were similar to the record of Larache. In contrast, hand capture yielded very low densities in human habitation and in animal shelters (less than 2 females/room) indicating the effectiveness of the insecticide used. On the other hand, the yields of CDC and UV light traps in human dwellings was very low, respectively 3.8 and 1 female/trap/night, compared with those of Larache. It is clear that the light traps were not capturing all the mosquitoes which entered to feed as evidenced by man-bait capture. In this particular case, it was assumed that despite the presence of the insecticide, the females still could enter the rooms and bite the sleepers, but they go out rapidly without being caught, as it seems that the attraction of the light trap was less powerful than the effect of the insecticide excitorepellency.

The processing of material collected by different methods rendered the following information:

(a) The sex ratio: The results were given for all species encountered in general but detailed data were tabulated showing the sex ratio of each species recorded by each method of capture. Although the sex ratio is generally close to 1:1 at emergence, most of the records show a marked departure from this ratio. The sex ratio was found to be much influenced by the site of capture. In the indoor resting shelters, the proportion of males varied from 0 to 14% (*labranchiae* 3-4%), while in the outdoor resting shelter, the proportion of males varied from 20 to 50% (*labranchiae* 40%). There was no appreciable difference between the indoor and outdoor resting shelters. The sheet trap attracted more male than CDC light traps placed outdoors, but the method which gave the highest percentage of males was hand capture in the outside resting shelters.
(b) The blood digestion stages: The highest proportion of unfed females was virtually observed by man-bait capture. Hand capture indoors gave an inverse proportion to those recorded by the light trap, as there was an excess of fed females resting indoors. The data for labranchiae were as follows:

<table>
<thead>
<tr>
<th></th>
<th>%UF</th>
<th>%F</th>
<th>%G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor resting (human shelter)</td>
<td>20</td>
<td>56</td>
<td>24</td>
</tr>
<tr>
<td>Indoor resting (animal shelter)</td>
<td>7</td>
<td>63</td>
<td>30</td>
</tr>
<tr>
<td>CDC (human shelter)</td>
<td>81</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>CDC (animal shelter)</td>
<td>78</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>CDC/UV (animal shelter)</td>
<td>88</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

Hand capture in outside resting shelters gave more balanced proportions of blood digestion stages for anophelines than culicines which showed an excess of unfed females. With labranchiae the proportions of UF, F and G were respectively 39, 21 and 40%. With CDC and UV light traps placed outside, the proportions of unfed females of labranchiae were high, 96 and 82% respectively. The sheet trap also gave a high proportion of unfed, 88%.

(c) Parous rate: The determination of the parous rate was made on the proportion of the unfed females collected by man-bait capture and CDC light traps indoors and outdoors, all of which gave comparable parous rates ranging from 82 to 95% for labranchiae, with the exception of samples collected at Sidi Yahia Boka station where man-bait capture gave a parous rate of 64% which was significantly different from 84% recorded in a sample of CDC light traps indoors.

For indicating the advantages and disadvantages of the different sampling methods, the author adopted the classification of the methods proposed by Service & Boorman (1965) as follows:

(1) Methods with no attraction:
- Hand capture in human habitation and animal shelters: This classical technique is simple and rapid to perform particularly with endophilic species such as labranchiae. The yield is usually high in animal shelters, if these are well constructed as in the case of human habitations. For evaluation of this technique, a pyrethrin solution in kerosene was sprayed following hand capture in small mud houses. It was realized that hand capture collected 47% of the anopheline populations resting in these houses. This percentage was even reduced in a large Saharan house with high inaccessible ceilings. Another inconvenience of hand capture is that some inhabitants refuse to admit the collectors to search their rooms.
- Collection from outside resting shelters: Collection by a sweeping net from vegetation is usually utilized in humid, sub-humid and semi-arid zones, while hand capture with an aspirator is used in arid and Saharan regions. These techniques are time consuming and usually give a poor yield. Nevertheless, they provide unbiased information on the exophilic fraction of the population.
- Malaise trap: This technique did not give satisfactory results in the present trial. In addition, it takes a long time to assemble and mount its parts, with frequent breakage during strong winds.

(2) Methods utilizing bait attraction:
- Man-bait capture: This is an indispensable technique for collecting species of medical importance, and obtaining information on the time and site of their aggressivity. Its disadvantages lie in the exhausting night work and the problem of finding temporary workers at high cost. Furthermore, in North Africa, inhabitants object to the presence of strangers in their houses all night and this creates a much more difficult situation than with day-time work.
- Man-baited nets: This technique is less exhausting because the subject can sleep all night, but the yield is far inferior to that of direct man-bait capture conducted concurrently nearby.
(3) Methods utilizing light attraction:

- CDC light trap: This trap collected all the anthropophilic mosquito species in larger numbers than man-bait capture. Its yield is optimum when utilized in closed places. The trap also collects exophilic species which enter houses for a short period to feed. The majority of the females collected by this trap were unfed, but there was also a certain proportion of fed mosquitoes caught. This proportion allowed the determination of the origin of bloodmeals (see the initial observations by the light traps above). The material collected by the light trap was usually in good condition; the collection of predators such as ants was rare in Morocco. The mortality in the collecting bag increased as the densities of mosquitoes increased, and it was also influenced by the amount of voltage and the aridity of the air. In the arid and Saharan zones, it is necessary to ensure that the collecting bag is kept humid if live mosquitoes are required. With regard to handling, the light traps are robust, easy to assemble, and their cost is reasonable. Moreover, the inhabitants welcomed the installation of the light traps in their houses; in fact the family chief who refused the work of man-bait capture, accepted and himself installed the light-trap in his room until it was collected in the morning by the operator.

- CDC/UV: This trap collected more mosquitoes of species that are of major interest in Morocco than the normal CDC trap, but the mortality in the collecting bag was high, possibly because this trap attracts high densities entering the room where it is placed. However, as indicated above, this trap is difficult to repair and transport with a 12 volts battery which also needs to be recharged frequently. Moreover, the light of this trap is so intense that it troubles the inhabitants and disturbs their sleep.

- Sheet trap: This trap permitted the collection of all culicine and anopheline mosquito species encountered in the present study. It was utilized mostly in itinerant missions for faunistic studies since it collected a large number of male mosquitoes.

In her conclusions, the author reiterated that the normal CDC light trap represents a useful tool for sampling all anthropophilic species of mosquitoes in Morocco. Despite the presence of certain quantitative and qualitative differences, the sample of Culicidae was very close to that collected by man-bait capture. The use of the CDC trap in Morocco should permit the determination of the seasonal prevalence of anthropophilic mosquito species, reducing the need for more frequent man-bait capture. However, it would be useful to compare the results of the two techniques from time to time.

The results of sergentii and other anophelines collected during this trial are shown under paragraph 2 below.

In Syria, Sadek (1984) during his assignment to assess the effectiveness of permethrin house spraying (see 1.6/1.7 above) tried to assess the CDC light trap as an additional tool for collecting the local malaria vectors, especially sacharovi, to be utilized in longitudinal studies. Four CDC light traps were used, but no information was given as to the sites and the procedures of operating these traps. It seems that they were only placed indoors. The traps gave unsatisfactory results in both permethrin treated and untreated villages. In the treated village, the density of sacharovi before spraying was 3.5 females/trap/night. After spraying, the female density fell to 1 sacharovi and 2 superpictus/trap/night. In the untreated village, the density was 2 sacharovi/trap/night, but dropped to zero at the end of September due to the onset of cool weather. On the other hand, the light trap gave a good yield of culicine mosquitoes before and after spraying. From these observations, Sadek concluded that the light traps are not suitable for sampling sacharovi in Syria compared with other sampling methods.

[Experience with light traps varied greatly. Although the light traps gave variable results with the An. gambiae complex and An. funestus in West Africa1, they performed satisfactorily in East Africa2. It seems that the variability of local conditions and the design of the experimental procedures are among the factors influencing the success or failure of the light traps as sampling tools. Although there is almost an agreement that

1. See PART I, document VBC/85.1 - MAP/85.1, SECTION III(A) WEST AFRICA (under 1.8), pp. 82-88.
2. See PART I, document VBC/85.3 - MAP/85.3, SECTION III(D) EAST AFRICA (under 1.8), pp. 68-71.
the light traps cannot replace the epidemiologically relevant technique of man-bait
capture, they can be useful tools for sampling anopheline fauna including exophilic species
that are rarely found resting in houses, and for collecting samples for dissections).

1.9 Host feeding patterns

Results of some precipitin tests carried out on bloodmeal smears of labranchiae as part
of studies on its biting and resting behaviour in Sicily, Italy, and in conjunction with
sampling by light traps in Morocco, have already been given above (see 1.6-1.7 and 1.8).

In Greece, Hadjinicolaou & Betzios (1973a) for their investigation on the feeding
behaviour of sacharovi at Thermopylae, Lamia plain, collected bloodmeal smears of females
of this species found resting in human dwellings, animal shelters and artificial
pit-shelters during 1968. The results showed that 61.5% of 260 smears from human dwellings
that gave a positive reaction, were positive for man. This high proportion was recorded at
that village when the man:animal ratio was 1:9 or 1:7.2 during the peak of the summer
season. This result was comparable to that recorded during 1932-1934 by Barber & Rice
(1935) when 61.3% of 3980 positive smears of sacharovi resting in houses, were positive for
man. This was taken to indicate that sacharovi in Greece has remained anthropophilic, 12
years after the cessation of DDT house spraying. However, a further sample of smears
collected and analyzed during 1970, gave 38.5% positive for man. Some explanation for this
reduction in the human blood index was offered in a further paper as shown below.

Garrett-Jones & Boreham (1973) analyzed the data of precipitin tests carried out on
samples of bloodmeal smears of sacharovi collected by Hadjinicolaou & Betzios from
Thermopylae during 1970 and 1971 with a view to determining the prevalence of mixed feeds.
Exhaustive precipitin testing (designed to detect mixed meals) of 1025 bloodmeals from
three different biotopes: human dwellings, two animal sheds and two pit-shelters revealed
that 91 or 8.9% of 1021 positive smears contained blood from two serologically distinct
hosts. In a routine survey made in 1971, when testing was not exhaustive, mixed meals were
detected in only 2 or 0.1% of 1798 positive smears tested. In the 1970 collection, no
mixed meals were found in pit-shelters, suggesting that a mosquito interrupted while
feeding outside tends to move to an indoor biotope to complete its meal. The proportion of
mosquitoes with multiple meals, i.e., those completing their feeding on the same host
species, could not be detected by the precipitin test. The frequencies of these "cryptic"
multiple meals could be computed for three main biotopes studied. Further, the authors
remarked that the data of 1970 showed that the most important hosts of sacharovi in cattle
sheds were sheep (or goats) and Equidae, whereas in the sample from human dwellings, the
blood of man and pig was the most prevalent. It was explained that most houses in
Thermopylae are fitted with window screens against mosquitoes, hence it was difficult to
collect large numbers of specimens. In fact, the majority of blood-fed females from this
biotope came from a single room in which the screens were in poor condition and which
overlooked a yard where pigs were kept. For this reason, the sample from houses was
probably not representative in that it contained a lower proportion of human (and possibly
more mixed meals) than might have been expected in typical houses of the village.

The most recent consolidated data of precipitin testing was tabulated by Garrett-Jones,
Boreham & Pant (1980) for the period 1971-1978. From these data, the results of tests on
the An. maculipennis complex from the Mediterranean Basin are shown in Table 5.

From this table, it is clear that as can be expected, samples of the An. maculipennis
complex derived from O biotope, i.e., with non-human hosts gave no or very low positive
reaction for man. In contrast, samples derived from human dwellings whether in unsprayed
or ex-DDT areas, gave moderately higher human blood indexes (HBI), the exception being the
records of maculipennis s.l. from Yugoslavia in 1974 and 1977. Only a single sample of
labranchiae from H biotope came from a DDT sprayed area in Morocco, which gave as low as 2%
man-positive smears, while the remaining smears were positive for animals (79% for bovids
and 19% for other animals). No information is available on the ecological conditions
associated with this biotope that may have influenced this pronounced zoophily. However,
this indicates an epidemiologically favourable trend, but the sample size was too small to
allow drawing a generalized conclusion.

<table>
<thead>
<tr>
<th>Country</th>
<th>Species</th>
<th>Year</th>
<th>Spray status</th>
<th>Resting biotope</th>
<th>No. smears giving +ve reaction</th>
<th>% +ve for primate blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>maculipennis s.l.</td>
<td>1973</td>
<td>N</td>
<td>O</td>
<td>48</td>
<td>0</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>maculipennis s.l.</td>
<td></td>
<td>ex-DDT</td>
<td>H</td>
<td>125</td>
<td>16.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1975</td>
<td>&quot;</td>
<td>O</td>
<td>739</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1976</td>
<td>N</td>
<td>H</td>
<td>116</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1977</td>
<td>N</td>
<td>O</td>
<td>1030</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
<td>ex-DDT</td>
<td>73</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
<td>O</td>
<td>1568</td>
<td>0</td>
</tr>
<tr>
<td>Spain</td>
<td>atroparvus</td>
<td>1973</td>
<td>N</td>
<td>H</td>
<td>56</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
<td>N</td>
<td>203</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
<td>ex-DDT</td>
<td>50</td>
<td>24</td>
</tr>
<tr>
<td>Algeria</td>
<td>labranchiae</td>
<td>1973</td>
<td>N</td>
<td>O</td>
<td>142</td>
<td>1.4</td>
</tr>
<tr>
<td>Morocco</td>
<td>labranchiae</td>
<td>1971</td>
<td>N</td>
<td>H</td>
<td>64</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
<td>DDT</td>
<td>48</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
<td>ex-DDT</td>
<td>210</td>
<td>34.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1973</td>
<td>DDT</td>
<td>O</td>
<td>318</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ex-DDT</td>
<td>O</td>
<td>206</td>
<td>11.7</td>
</tr>
<tr>
<td>Tunisia</td>
<td>labranchiae</td>
<td>1974</td>
<td>ex-DDT</td>
<td>H</td>
<td>110</td>
<td>64.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
<td>O</td>
<td>219</td>
<td>15.1</td>
</tr>
<tr>
<td>Greece</td>
<td>sacharovi</td>
<td>1971</td>
<td>ex-DDT</td>
<td>[O]</td>
<td>537</td>
<td>0.9</td>
</tr>
<tr>
<td>[Thermopyla]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>sacharovi</td>
<td>1973</td>
<td>ex-DDT</td>
<td>O</td>
<td>127</td>
<td>2.4</td>
</tr>
</tbody>
</table>

N = Never sprayed.
ex-DDT = Indicates that an area was last sprayed more than 12 months before sampling.
H = Human and mixed dwellings.
O = All daytime-resting biotopes where man is not available [This combines animal sheds and outside-resting shelters].
[O] = This code was marked by the writer as it is clearly shown in the paper of Boreham & Garrett-Jones (1973) that the samples of 537 smears came from animal sheds only.
1.10 Longevity

The most detailed and intensive work on this aspect was carried out in the USSR covering the potential vectors of the *An. maculipennis* complex for which the monograph of Detinova (1962) should be consulted. Apart from that, there is no information available on age-grading of field populations of the *An. maculipennis* complex in the Mediterranean Basin except the work done in Sicily, Italy, during the 1960's-1970's.

Cefalù, Oddo & Sacci (1961) during their studies on the behaviour of *labranchiae* in Roccamena area of Sicily, Palermo province (see under 1.6-1.7 above) applied Polovodova's technique (see Detinova, 1962) for determining the physiological age of the populations of this species sampled from houses and natural shelters. A summary of the data is shown in Table 6.1


<table>
<thead>
<tr>
<th>Period</th>
<th>Site of capture</th>
<th>No. dissected</th>
<th>Nulliparous</th>
<th>Parous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>22.09.60-</td>
<td>Houses</td>
<td>101</td>
<td>19*</td>
<td>57*</td>
</tr>
<tr>
<td>28.11.60</td>
<td>%</td>
<td>18.8</td>
<td>56.4</td>
<td>16.8</td>
</tr>
<tr>
<td>26.09.60-</td>
<td>Natural shelters</td>
<td>33</td>
<td>8*</td>
<td>18</td>
</tr>
<tr>
<td>01.05.61</td>
<td>%</td>
<td>24.2</td>
<td>54.6</td>
<td>18.2</td>
</tr>
<tr>
<td>Total houses &amp; natural shelters</td>
<td>134</td>
<td>27</td>
<td>75</td>
<td>23</td>
</tr>
</tbody>
</table>

* A small number of females were non-gonoactive and contained fat body during September-November.

It is clear that *labranchiae* in the study area had a short physiological age, with the majority of the females falling within the nulliparous and primiparous groups, and only a few females could complete the 4th gonotrophic cycle. The dominance of physiologically young mosquitoes was explained as probably having been due to the persistence of active DDT deposits in many indoor shelters three years after the last spray creating an impact on vector density and age. As shown above, the dissections made in the autumn showed the presence of a proportion of *labranchiae* females with well developed fat body and inactive ovaries. This provided an example of the variability of behaviour of *labranchiae* under different ecological conditions existing in the same region. The study area of Roccamena is at 500 m altitude above sea-level. This phenomenon of diapause was less pronounced in coastal areas, where the ovarian development slowed down but did not become completely arrested (citing Mariani & Cefalù, 1954).

Also in Sicily, Valentino & Bruno Smiraglia (1965) carried out a detailed study of the physiological age of *labranchiae* during 1964 in two different areas. Periodic collections were made from January to December 1964 in various localities of Trapani province in which the annual DDT spraying was started in 1947 and ended in 1964. For comparison, collections of the same species were made in some localities in Palermo province in which DDT spraying was also started in 1947 but discontinued in 1961. The dissection followed the technique of Polovodova (in Detinova, 1962) for determination of the detailed physiological age of *labranchiae* populations. Detailed data of monthly

1. By permission of Dr F. Oddo and *Parassitologia* from the paper of Cefalù, Oddo & Sacci (1961).
2. The authors' summaries of this paper and the paper of Cefalù, Oddo & Sacci (1961) were expanded through the kind cooperation of Dr F. Oddo.
dissections made in 1964 were tabulated, but it is sufficient here to give the consolidated totals for the whole year as shown in Table 7.¹

Table 7. Determination of the physiological age of labranchiae in Sicily, 1964.

<table>
<thead>
<tr>
<th>Area</th>
<th>No. examined</th>
<th>Inseminated %</th>
<th>Nulliparous %</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapani province</td>
<td>488</td>
<td>77.46</td>
<td>51.43</td>
<td>39.55</td>
<td>9.02</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DDT:1947-64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palermo province</td>
<td>811</td>
<td>95.31</td>
<td>34.15</td>
<td>46.12</td>
<td>19.03</td>
<td>3.5</td>
<td>0.5</td>
</tr>
<tr>
<td>DDT:1947-60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These data clearly indicate that in the area still under DDT spraying only 9.02% of the labranchiae population completed the 2nd gonotrophic cycle, and none had reached the 3rd gonotrophic cycle, whereas in the area where DDT spraying was discontinued in 1960, there was a proportion of the females that could complete four gonotrophic cycles. However, the longevity was not as great as that of labranchiae existing in areas that have never been sprayed. These observations agreed with those of Cefalù, Oddo & Saccà (1961) in that the residual effect of DDT may shorten the mean age of the labranchiae population even as long as four years after the last spraying. This also confirms the unchanged susceptibility of labranchiae to DDT in Sicily. Examination of the spermathecae showed that in the area still under DDT spraying about 22.5% of the females were not inseminated, whereas in the area where DDT was discontinued, only 4.7% of the females were not inseminated. This may have been caused by different factors, amongst which is the greater susceptibility of labranchiae males to DDT.

Further work in Sicily on the physiological age of labranchiae was carried out by D'Alessandro, Bruno Smiraglia & Lavagnino (1971) as part of their studies on the bioclimatic of this species 10 years after DDT spraying was discontinued (see 1.5 above). The results of dissections made during the seasonal prevalence of labranchiae are shown in Table 8.²

Table 8. Observations made on adult females of labranchiae collected in several places in Sicily in the period from April to September 1967.

<table>
<thead>
<tr>
<th>Month</th>
<th>Number of females</th>
<th>Mated</th>
<th>Nulliparous</th>
<th>Parous</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>46</td>
<td>46</td>
<td>27</td>
<td>19</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>June</td>
<td>270</td>
<td>261</td>
<td>139</td>
<td>96</td>
<td>31</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>July</td>
<td>230</td>
<td>226</td>
<td>91</td>
<td>90</td>
<td>39</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>August</td>
<td>605</td>
<td>602</td>
<td>216</td>
<td>211</td>
<td>101</td>
<td>57</td>
<td>15</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>September</td>
<td>488</td>
<td>482</td>
<td>191</td>
<td>224</td>
<td>59</td>
<td>13</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1 639</td>
<td>1 617</td>
<td>664</td>
<td>640</td>
<td>230</td>
<td>80</td>
<td>19</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>%</td>
<td></td>
<td></td>
<td>40.5</td>
<td>39</td>
<td>14</td>
<td>4.9</td>
<td>1.2</td>
<td>0.4</td>
<td>-</td>
</tr>
</tbody>
</table>

From these data, it is clear that during the favourable season nearly all the females of labranchiae were inseminated. At the beginning of the season the population was largely formed of newly emerged females of the summer generations (58.7%), and a proportion of females which completed one gonotrophic cycle (41.3%). As the season progressed, the parity of the population increased and more aged individuals appeared. The maximum physiological age of five gonotrophic cycles was observed in July and August. [This shows that labranchiae populations can reach a potentially dangerous age from an epidemiological standpoint during summer months when it can transmit P. vivax, if suitable imported cases

¹ Reproduced by permission of Prof. L. Valentino from the paper of Valentino and Bruno Smiraglia (1965), but permission from Rivista di Malariologia could not be obtained as this Journal has been discontinued.
² Tables 8 and 9 have been reproduced by permission of Prof. A. Lavagnino, from the paper of D'Alessandro, Bruno Smiraglia & Lavagnino (1971).
of gametocyte carriers become available]. The results of age-grading 
larval populations in winter are shown under 1.5 above.

Observations were made on the duration of the second phase of the gonotrophic cycle, i.e., the time taken for blood digestion and maturation of the ovary (Detinova, 1962) in 
larval populations under natural conditions. Engorged females were kept in a cattle stable at 
Fellamonica until the ovaries matured. The results are shown in Table 9 (see footnote 2 on 
previous page). It can be seen that during July-August the eggs of larvae needed 5-6 
days to mature. All females which had not oviposited were found to contain eggs at 
Christophers' stage V. The period required for maturation of the ovaries did not vary much 
in nulliparous and parous females.

In Turkey, Kasap et al. (1990) determined the physiological age of s accelerate during 
its seasonal prevalence and its hibernation. The study was conducted in Menekge village, 
at about 10 km from Çukurova University. Collection of s accelerate was made at fortnightly 
intervals and continued for one year. Females were classified according to the blood 
digestion stages (UF, F, G) and the presence of fat body was recorded. From April to 
August, gravid females constituted 60.2 ± 11.8% of the collection, and from October to 
February, unfed females constituted 47.6 ± 20.8% of the collection, and those which had fat 
body constituted 24.8 ± 11.2% of the collection. Dissections showed that females which 
laid once (1-parous) were recorded during April-June, and those which laid twice (2- 
parous) were found during July-September. From December to March, only inseminated 
nulliparous females were encountered, and from November to January the population was 
characterized by an increasing number of females with fat body. This was described as 
being a condition of gonotrophic dissociation characterized by cessation of ovarian 
development despite continuous feeding on blood. The gonadactive period of s accelerate 
ocurred during April-October. By placing caged females of s accelerate under simulated 
natural conditions in Menekge village, the life span of this species was estimated as 20 
weeks on an average. This period was considered to be long enough for P. vivax to complete 
its sporogonic cycle in s accelerate.

[Perhaps the full text of this paper when published may give some explanation regarding the 
absence of s accelerate females older than 2-parous, and may also provide information on the 
duration of the gonotrophic cycle during the favourable season].

1.1. Natural infection

Old records of infection rates in the An. maculipennis complex by Boyd (1949-VOL. I) 
and Horsfall (1955) for these books should be consulted. It is useful, however, to 
recall some of these records of sporozoite rates in certain members of this complex. In 
Bulgaria, Drensky & Collins (1934) noted that it was common knowledge among private 
practitioners and malaria staff in Petrich area to find malaria cases among winter-borne 
infants who presented acute attacks in April-May. Additionally, there were cases among 
adults who had apparently never had an acute attack of malaria but presented acute sympotms 
in the spring. In the latter case, however, the possibility of latent infections acquired 
during the previous autumn could not be excluded. Reports of other authors in Italy and 
the Netherlands that indicated the presence of infected anophelines among hibernating 
mosquitos, especially those resting in houses, were cited. Reference was also made to 
other reports indicating that in Macedonia oocysts were found in hibernating mosquitoes. In 
the hope that additional light might be thrown on the possibility of new infections to be 
acquired in the spring, the authors carried out a series of dissections of the most 
important vectors in Bulgaria: maculipennis [s.l.] and superpictus, during February-April 
1933.

1. Detinova (1962) defined the duration of the gonotrophic cycle as the sum of the 
following three phases:
(a) the search for a host and inflicting a bite;
(b) the digestion of the bloodmeal and maturation of the ovaries; and
(c) the search for a suitable breeding site and ovipositing.
2. An English summary of this paper (in press) was provided through the kind cooperation of 
Prof. H. Kasap (personal communication, January 1990).
Table 9. Observations on the duration of second phase of the gonotrophic cycle in *labranchiae* under natural conditions (cattle stable at Fellamonica)

<table>
<thead>
<tr>
<th></th>
<th>Temperature °C</th>
<th>Humidity %</th>
<th>Days to mature eggs</th>
<th>Number females</th>
<th>Females not oviposited Christopher's Stage V</th>
<th>Females oviposited Christopher's Stage II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min. max.</td>
<td>min. max.</td>
<td></td>
<td></td>
<td>Nulliparous 1 2 3 4</td>
<td>Parous 1 2 3 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 1</td>
<td>21 30</td>
<td>50 95</td>
<td>6</td>
<td>43</td>
<td>1 2 2 - -</td>
<td>7 25 5 1</td>
</tr>
<tr>
<td></td>
<td>12 19 28</td>
<td>60 95</td>
<td>6</td>
<td>6</td>
<td>- 5 - -</td>
<td>1 - -</td>
</tr>
<tr>
<td>15</td>
<td>20 29</td>
<td>60 95</td>
<td>6</td>
<td>11</td>
<td>3 - - -</td>
<td>1 5 5 -</td>
</tr>
<tr>
<td>21</td>
<td>22 28</td>
<td>70 95</td>
<td>5</td>
<td>15</td>
<td>1 3 - -</td>
<td>7 3 1 -</td>
</tr>
<tr>
<td>August</td>
<td>22 30</td>
<td>65 85</td>
<td>5</td>
<td>19</td>
<td>3 6 2 2</td>
<td>2 3 1 -</td>
</tr>
<tr>
<td>14</td>
<td>20 31</td>
<td>80 90</td>
<td>5</td>
<td>49</td>
<td>11 13 5 2 -</td>
<td>12 4 1 1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td>286</td>
<td>19 29 9 4 -</td>
<td>30 40 9 2</td>
</tr>
</tbody>
</table>
The results are summarized below (data of *superpictus* are given here for comparison):

<table>
<thead>
<tr>
<th>Maculipennis s.l.</th>
<th>Superpictus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. dissected</td>
</tr>
<tr>
<td>February</td>
<td>208</td>
</tr>
<tr>
<td>March</td>
<td>307</td>
</tr>
<tr>
<td>April</td>
<td>94</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>609</strong></td>
</tr>
</tbody>
</table>

It is clear that the infected specimens of *maculipennis* s.l. were almost exclusively with sporozoites, while in the infected *superpictus* only oocysts were found. This was the reverse of the condition observed at the end of the previous summer, when *maculipennis* showed a much larger proportion of oocyst-positive specimens, while in *superpictus* only sporozoite-positive females were seen. It was interesting to note that the occurrence of *P. falciparum* infection coincided with a high sporozoite rate in *superpictus* in late summer and autumn, while the occurrence of *P. vivax* corresponded with a high sporozoite rate in *maculipennis* s.l. in the early spring. Precipitin tests carried out on bloodmeals of females caught in March-April showed that an appreciably higher proportion of man-fed *maculipennis* s.l. existed than at other periods of the year. It was concluded that there is a real possibility that new malaria infections may occur as a result of infected hibernating anophelines, and this may explain the epidemic rise of malaria in the spring which was so characteristic of the disease in the Petrich area of Bulgaria.

In Greece, Barber & Rice (1935) carried out a study of malaria infection rates in *sacharovi*, *maculipennis* (messeeae and typicus) and *superpictus* during April 1932-December 1934, as these species were the vectors of *P. vivax*, *P. falciparum* and *P. malariae*. Mosquito collections were made from a region representing all northern Greece except for some localities in which domestic animals were less abundant. Nearly all villages were within 50 km of Cavala city, but at the beginning of 1933 the study area was extended to include some new villages, of which several highly endemic villages were situated near the Nestos River. A summary of the results of sporozoite rate determination made monthly (excluding March) over the 3-year study period follows:

<table>
<thead>
<tr>
<th>Sacharovi</th>
<th>Maculipennis</th>
<th>Superpictus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. sporozoite %</td>
<td>No. sporozoite %</td>
</tr>
<tr>
<td>1932</td>
<td>8997</td>
<td>1.22</td>
</tr>
<tr>
<td>1933</td>
<td>9140</td>
<td>1.45</td>
</tr>
<tr>
<td>1934</td>
<td>4063</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Dissections made in the winter months of 1933 gave high sporozoite rates in *sacharovi*: 2.6% in January (189 dissected) and 1.7% in February (178 dissected), but none in *maculipennis*, and only 0.6% in *superpictus* (728 dissected) in February.

From these data, it appeared that *sacharovi* was the chief vector of malaria in the study area during the three years. The sporozoite rate of *maculipennis* (messeeae and typicus) was very low, and epidemiological evidence indicated that the role of *superpictus* in malaria transmission was unimportant, at least in the last two years. The sporozoite rates of all species declined during the past three years, and this decline was associated with diminishing parasite rates in the human population. A decrease in rainfall, affecting the density of *sacharovi* in particular, seemed to have been responsible for the fall in the parasite and gametocyte rates in the human population.

In Turkey, Kasap et al. (1981) started in 1977 a programme of research on mosquitoes and malaria in Çukurova where malaria was widespread. In this area, the mosquitoes which are likely to transmit *P. vivax* malaria were: *sacharovi*, *superpictus* (see under 2.11 below) and *hyrcanus* (see under 4.1 below). A sample of 200 females of *sacharovi* was collected from some villages in Kigla district (Adana) and dissected in the laboratory. Four of these (2%) were oocyst- and sporozoite-positive. Kasap et al. (1988) further studied experimentally the sporogonic development of *P. vivax* in *sacharovi* originating from the Adana area. Of 792 females of *sacharovi*, 72% obtained a bloodmeal from 19 *P. vivax* patients. Oocysts were observed from days 2 to 16 and the sporozoites in the salivary glands on days 8 to 36 after the infected bloodmeal. Starting from day 8 post infection, the sporozoite rate gradually increased reaching 75% and 100% on day 20 and 26.
respectively. The mean sporozoite density per salivary gland ranged from 500 to 1000 during days 8 to 34. The authors concluded that in addition to the man biting rate and the longevity of *sacharovi*, its susceptibility to *P. vivax* makes it an efficient vector for *vivax* malaria. It may be due to such characteristics of *sacharovi* that even in periods of low density, malaria transmission continued in villages of Çukurova region in south Anatolia. Moreover, the magnitude of malaria cases in this region seems to correlate positively with the density of *sacharovi*. Thus, this species still remains the most important vector of malaria, besides which *superpictus* and other suspected vectors such as *maculipennis* s.s. and *byrcanus* may play a role.

In Israel, Saliternik (1974) recalled several old records of sporozoite rates in *sacharovi* obtained by various authors mostly in winter months as follows: 4.2% (95 dissected) during December, citing Reitler & Saliternik (1929); 1.1-5.4% (2400 dissected) during January-December, citing Kligler (1930); 0.4% (525 dissected) during October-December, citing Lumsden & Yoffe (1950).

1.12 Vector resistance to insecticides

As mentioned in the INTRODUCTION, the recent status of vector resistance to insecticides is extracted from the tabulated data of the last two reports of the WHO Expert Committee (WHO, 1980 - TRS. No. 655, and WHO, 1986 - TRS. No. 737). Data for members of the An. *maculipennis* complex are shown here in Table 14.

Table 10. Insecticide resistance in the An. *maculipennis* complex

<table>
<thead>
<tr>
<th>Species</th>
<th>DDT</th>
<th>Dieldrin/HCH</th>
<th>OP/carbamate</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>atroparvus</td>
<td>Portugal, Romania, Spain, USSR, UK</td>
<td>Bulgaria, Romania, Spain</td>
<td>-Portugal: fenitrothion, chlorphoxim/carbamate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Romania: fenitrothion, fenthion, chlorphoxim/carbamate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Spain: malathion, fenitrothion, fenthion, chlorphoxim/carbamate</td>
<td></td>
</tr>
<tr>
<td>labranchiae</td>
<td>Algeria, Morocco, Tunisia</td>
<td>Algeria, Morocco</td>
<td></td>
<td></td>
</tr>
<tr>
<td>maculipennis</td>
<td>Greece, Romania, Turkey, USSR</td>
<td>Greece, Turkey</td>
<td>-Greece: fenitrothion/carbamate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Romania: fenitrothion, fenthion, chlorphoxim/carbamate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Turkey: fenitrothion, jodfenphos, carbamate</td>
<td></td>
</tr>
<tr>
<td>melano</td>
<td>Turkey</td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>messeae</td>
<td>Bulgaria, Romania, USSR</td>
<td>Bulgaria, Romania</td>
<td>-Romania: malathion, fenthion</td>
<td>-USSR: carbamate</td>
</tr>
<tr>
<td>sacharovi</td>
<td>Bulgaria, Greece, Lebanon, Syria, Turkey, USSR</td>
<td>Bulgaria, Greece, Lebanon, Syria, Turkey</td>
<td>-Bulgaria: fenitrothion/carbamate</td>
<td>-Lebanon: fenitrothion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Greece: fenitrothion/carbamate</td>
<td>-Syria: fenitrothion/carbamate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Turkey: malathion, fenitrothion, fenthion, jodfenphos, pyrethroids, chlorpyrifos, chlorphoxim, paraquat/carbamate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-USSR: carbamate</td>
<td>-</td>
</tr>
</tbody>
</table>

In the list of species and countries where insecticide resistance has had epidemiological or economic impact and/or necessitated a change in control operations (WHO, 1986 - TRS. No. 737), DDT resistant *sacharovi* in Syria, Turkey and the USSR was included.
In the same report the available findings on resistance mechanisms in anophelines and culicines were summarized. The data pertaining to members of the An. maculipennis complex are shown here in Table 11.

In a recent communication by Lavagnino (1983), labranchiae in Sicily, Italy was shown to be completely susceptible to DDT and malathion as indicated from susceptibility tests carried out annually during 1964-1971. Between 1972-1977, labranchiae was so scarce that only a limited number of susceptibility tests could be made. This was tentatively attributed to the increasing use of pesticides in agriculture, which could not be controlled and evaluated. During 1979-1980, the density of labranchiae considerably increased in many areas of Sicily. Tests were carried out during the summer of 1981 and 1982 in Palermo, Trapani and Agrigento areas. The tests showed marked reduction in mortalities on 2% DDT (from 90% previously to 40 or even 20% in Palermo), and on 0.5% malathion (from 60 to 20 or even zero in Palermo and Agrigento). Although labranchiae in Sicily was still killed by the discriminating dosages, i.e., no survival of adults with one hour exposure to 4% DDT, 5% malathion, 1% fenitrothion and 0.1% propoxur, there was evidence that this mosquito, which has shown constant susceptibility to DDT and malathion during the past 20 years, was exhibiting a slight decrease in susceptibility, as indicated from exposures to the lower dosages of the two insecticides. This was interpreted as "vigour tolerance" rather than resistance.

From the reports of field susceptibility tests communicated to WHO during 1984-1988, records indicating the presence of resistance (R) or requiring verification (V)\(^1\) are shown in Table 12.(See footnotes of Table 12 for explanation of R and V).

The details of tests carried out on sacharovi with different insecticides in Syria during 1985 were listed in an unpublished report to WHO by Eshghy (1986). The tests of permethrin indicating the need for verification and subsequently resistance in 1985 were shown as follows:

<table>
<thead>
<tr>
<th>Locality (City Province)</th>
<th>Date</th>
<th>Spraying History (rounds)</th>
<th>Permethrin Concentration</th>
<th>Mortality(^*) (Number exposed)</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheikh-Hadid, (Hama)</td>
<td>6-9 Jul.</td>
<td>DDT(10), DL(6), Mal(8), Perm(5).</td>
<td>0.25</td>
<td>89.1(211)V</td>
<td>88.9(45) R</td>
</tr>
<tr>
<td></td>
<td>21 Aug.</td>
<td></td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tal-Keishour- Sourek (Aleppo)</td>
<td>22-23 Sept</td>
<td>DDT(10), DL(6), Mal(8), Perm(5).</td>
<td>81.5(92)V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 Sept</td>
<td></td>
<td></td>
<td></td>
<td>74.1(27) R</td>
</tr>
</tbody>
</table>

\(^*\)No mortality in the control was observed.
DL = dieldrin, Mal = malathion, Perm = permethrin.

The exposures of two hours were meant to be verification tests which tentatively confirmed the presence of permethrin resistance. The extent of this resistance in areas under permethrin spraying in Syria has to be delimited. Final confirmation, however, should be obtained by sending egg batches of survivors of future tests to a recognized laboratory where facilities for rearing and selection are available. If confirmed, comprehensive entomological/parasitological observations should be conducted to determine the operational implications of permethrin resistance in its area of distribution in Syria.
<table>
<thead>
<tr>
<th>Species</th>
<th>Origin</th>
<th>Insecticide resistance</th>
<th>Pattern of cross resistance</th>
<th>Resistant insect stage</th>
<th>Detection method</th>
<th>Enzyme</th>
<th>Type of change</th>
<th>Linkage</th>
<th>Mode of inheritance</th>
</tr>
</thead>
<tbody>
<tr>
<td>atroparvus</td>
<td>Spain</td>
<td>propoxur/ malathion</td>
<td>W</td>
<td>L/A</td>
<td>B,S,M</td>
<td>Acetylcholinesterase, oxidase</td>
<td>Qualitative</td>
<td>Unlinked to stripe</td>
<td>[Monofactorial for malathion; polyfactorial for propoxur]</td>
</tr>
<tr>
<td>labranchiae</td>
<td>Sicily</td>
<td>DDT/malathion</td>
<td>-</td>
<td>-/A</td>
<td>B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>maculipennis</td>
<td>Greece</td>
<td>propoxur/ fenitrothion</td>
<td>-</td>
<td>-/A</td>
<td>B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>sacherovi</td>
<td>Turkey</td>
<td>DDT</td>
<td>N</td>
<td>L/A</td>
<td>B,M,E</td>
<td>Dehydrochlorinase</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>propoxur/ fenitrothion</td>
<td>W</td>
<td>L/A</td>
<td>B,M,E</td>
<td>Acetylcholinesterase</td>
<td>Qualitative</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1. In this column emphasis is on the compound which is thought to have selected the resistance. Where the resistance has been selected in the field, and is almost certainly due to agricultural pesticides, OP compounds and/or carbamates are generally indicated.

2. The distinction between qualitative and quantitative change is not always clear. In many cases both types of change may be involved.

* [From Hemingway (1982a) and Hemingway & Davidson (1983) - see VOL. I, under 2.6.1, pp. 90-93].

N = Narrow spectrum of cross-resistance.  
W = Wide spectrum of cross-resistance.  
B = Bioassay [= susceptibility test].  
S = Synergistic test.  
M = Metabolic test.  
E = Enzyme assay.  
L = Resistant larval stage.  
A = Resistant adult stage.
### Table 12. Summary of susceptibility tests on in the An. maculipennis complex in the Mediterranean Basin communicated to WHO during 1984-1988

<table>
<thead>
<tr>
<th>Species</th>
<th>Country</th>
<th>Insecticide</th>
<th>Resistance status</th>
<th>Areas and Year</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>labranchiae</td>
<td>Tunisia</td>
<td>DDT</td>
<td>R</td>
<td>Bizerte(1985-1986)</td>
<td>Species still susceptible to malathion</td>
</tr>
<tr>
<td>sacharovi</td>
<td>Syria</td>
<td>DDT</td>
<td>R</td>
<td>Hama(1985)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>permethrin</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>permethrin</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>bromophos</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>pirimiphos- methyl</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>bendiocarb</td>
<td>V</td>
<td>Hama,Quneitra(1985)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>propoxur</td>
<td>V</td>
<td>Hama,Quneitra(1985)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>fenitrothion</td>
<td>V</td>
<td>Quneitra(1985)</td>
<td></td>
</tr>
</tbody>
</table>

1. R = Resistance is present when mortality is less than 80% on the diagnostic concentrations
2. V = verification is required when the mortality on the discriminating dosage is between 80-98%, according to the criteria proposed by Davidson & Zahar (1973) and adopted by the Expert Committee (WHO, 1986-TRS. No. 737, pp. 49-50) - verification tests are also explained.

2. An. sergentii and An. superpictus

The two species are dealt with here whether they occur singly or in association.

2.1 Vector importance

In continental Europe where malaria has been eradicated, superpictus is among the potential vectors in certain areas where it exists as in Italy, Yugoslavia, Bulgaria and the USSR. It also acts as a potential vector in Cyprus, where it has persisted after the Anopheles (malaria) eradication campaign. It is associated with sergentii and both act as potential vectors in Jordan and Israel where malaria transmission has been eliminated. In Turkey and Syria, superpictus is an important vector next to sacharovi.

An. sergentii has been known to be associated with oases malaria as in the south of Morocco and the Sahara of Algeria. It used to exist in south Tunisia until it disappeared following insecticidal aerial spraying but reappeared later creating problems of malaria transmission in several foci (see under 2.1 below). It persists in Libya as a potential vector in the southern oases. In Egypt, it acts as a main vector of malaria in the oases of the western desert and in Fayyum governorate where it is associated with pharoensis. An exceptional record of sergentii which represented its northernmost limit of distribution in the Mediterranean Basin came from Bulgaria, but no information was provided on the locality of this record nor on the involvement of this species in malaria transmission. A second record from the northern part of the Mediterranean Basin came from Pantelleria island, Sicily, Italy, where it was associated with a few malaria indigenous cases (see under 2.5 below).
2.2 Breeding habitat

Service (1986) described the breeding places of superpictus as torrents of shallow water over rocky streams, pools in rivers, muddy hill streams in which vegetation may be present - the larvae prefers sunlight. He also described the breeding places of sergentii as rice fields, burrow pits, ditches, seepages, slow flowing streams - sunlit or partially shaded.

In the USSR, Artemiev (1980) described the breeding places of superpictus as shallow water bodies in mountain streams with gravel beds. The water in these is rich in calcium salts, and the vegetation consists of filamentous algae. The water in the breeding sites is standing or slow-moving. In the daytime, the water temperature usually rises to 35-38°C, and optimum breeding temperature is about 30°C. At this temperature, the whole developmental period takes no more than 11 days, as compared with 24 days at 19-20°C. The larvae of superpictus may breed in other types of water bodies including rice fields provided that the calcium contents are high. The breeding requirements of superpictus are the presence of warm water preferably flowing streams with high contents of calcium salts. These conditions determine the landscape and geographical distribution of this species. The best conditions for superpictus are found in Central Asian mountains where summers are hot and dry, and the rivers become largely dry. In the Caucasus, with a damp climate, rains are frequent in summer, and the temperature is relatively low: the density of superpictus is low, while the highest density is shown by maculipennis s.s. In Central Asia, superpictus can be found in the mountains up to 2300 m altitude.

In Turkey, Postiglione, Tabanli & Ramsdale (1973) found that the breeding places of superpictus in Turkey do not differ from those of other parts of its distribution range, which include unshaded gravel margins of seepages of ditches and streams, residual pools in drying stream beds and other pools fed by seepages. The most suitable sites are pools formed at the edges of streams, where the flow is restricted but the water is still connected with the main stream. With its preference to hill stream, superpictus density increases as the flow diminishes extending the amount of pooling. In dry years the density peak tends to appear earlier. On the other hand, a small rise in the stream level caused by rains in the mountain catchment area can control superpictus output through the flushing out of the breeding places. Consequently, the densities of this species tend to fluctuate with the local patterns of rainfall.

Regarding sergentii, Senevet & Andarelli (1956) summarized the available information on its breeding habitat in the Mediterranean Basin. The breeding habitats of this species are very variable: rice fields, irrigation canals with weak current and ponds with dense vegetation. In the oases of the Sahara the following breeding places were encountered in Algeria: water cress beds (Adrar), puddles with clear sunlit water without vegetation (Djanet), pools of stagnant water congested with vegetation (Beni Ounif), and canals blocked with Potamogeton (Aharar). In northern Algeria, sergentii was found breeding in the blind ends of streams overgrown with grassy vegetation and green algae. At Bou Saada, its larvae were collected in a stream, and in a small sunlit reservoir covered with filamentous algae. The larvae were collected in water containing 2.23 g NaCl/l. The pH of the water varied between 5 and 9, and the temperature range was 10-20°C.

In Libya, Macdonald (1982) noted that sergentii which is the most important vector in desert oases, usually breeds in shaded or unshaded slow-moving clean water such as seepages, springs, and irrigation canals, but it was also recorded from clean, still water in burrow pits.

In Egypt, Gad (1956) reviewed the records of mosquito species in the oases of the western desert adjacent to Libya, and included notes on the identification of material collected during the malaria control project in certain oases. An. sergentii was found in Siwa, Dakhia and Kharga oases breeding at the weedy edges of slowly running waters arising from wells and springs. Its larvae were also found in canals of rice fields and seepages, but rarely in wells. The seasonal prevalence of sergentii was the autumn and early winter. Few adults of superpictus were reported from Siwa by Salem (1933), but Gad (loc.cit.) indicated that examination of many thousands of larvae and adults collected over three years did not reveal the presence of superpictus in Siwa oases.

Further, a series of studies were carried out to determine the physical and chemical characteristics of breeding places of anopheline species occurring in different parts of
Egypt. The first of the series dealt with the types and characteristics of the breeding places as reported by Gad et al. (1982). The study was started in June 1978 and terminated in December 1979. The following areas were covered: 3 governorates in the Nile Delta namely Kafr El-Sheikh (15 localities), Damietta (10 localities), and Sharqiya (19 localities); Suez Canal zone (13 localities) and Faiyum governorate (23 localities). The study was extended to the oases namely: Siwa (6 localities - surveyed 3 times), Bahariya (4 localities, 3 times), the New Valley (23 localities in El-Kharga and Dakhla oases, surveyed twice), and Farafra (one locality visited once). For larval sampling, an enamel ladle having 10 cm in diameter was used in small breeding places, and a net dipper of 15 cm diameter was used in larger places. The density index was calculated on the basis of the number of larvae/10 dips. An. sergentii was found breeding in Faiyum and all oases of the western desert. The breeding places were characterized by having clear stagnant or slow moving water, and essentially contain vegetation. Water depth varied from shallow water to 10 m in depth as in wells. The different types of breeding places of sergentii encountered were:

(a) agricultural drains and irrigation channels which lead the water from wells or springs (in oases). These were found to have clean, shallow and slow moving water - larvae were mainly concentrated at the grassy edges.

(b) surface and seepage waters arising from wells or irrigation channels and usually covered with thick growth of vegetation or reeds; the water was usually fresh, but moderate salinity was sometimes encountered.

(c) rice fields were considered one of the principal types of breeding places of sergentii, particularly those having small or moderately growing plants.

(d) small water collections such as burrow pits.

(e) wells and springs of all sizes with varying depths and having vegetation on water surface or at the sides.

The larval density varied in different areas and according to the type of breeding place:

- In Faiyum, the density ranged from 0.13 larvae/10 dips in surface water or pools to 0.67 in the most preferred sites of small water collections.

- In Siwa oasis, the density ranged from 1 larva/10 dips in seepages to 2.23 in springs and wells, being the most preferred sites.

- In Bahariya oasis, the density ranged from 1.17 larvae/10 dips in springs and wells to 4.44 in the most preferred sites, being stagnant pools, drains and irrigation channels. In rice fields, the density was 2.42.

- In the New Valley, the density ranged from 0.94 larvae/10 dips to 6.09 in the most preferred sites, being drains and irrigation channels. The density in rice fields was 1.44.

Thus it seems that, in general, the most favourable breeding sites for sergentii were drains and irrigation channels, with one exception recorded in Siwa oasis where the density was generally low (0.4/10 dips). Rice fields yielded moderate density.

The second study concerned with the determination of the chemical characteristics of breeding waters of different Egyptian anophelines as reported by El Said et al. (1982). During larval surveys conducted in the governorates of the Nile Delta, Canal zone, Faiyum and the oases of the western desert, during 1978-1980 the pH and salinity of waters of different types of breeding places were determined. For sergentii, the results from Faiyum and all oases of the western desert showed a pH value ranging from 5.5 to 9 with a mean value of 7.01±0.07. Within this range larvae were most frequently encountered (79.1% of the total observations) and most abundantly in water having a pH value of 7 (88.2% of total observations). With regard to water salinity, the results from the same areas showed a range of 0.05-4.25 g Cl/L or 0.005-0.425% with a mean value of 1.07±0.20 g Cl/L or 0.005. Water with low salinity (less than 1 g Cl/L or 0.1%) appeared to be the most suitable for larval breeding. Within the above range of salinity, the highest frequency of
lunar occurrence was encountered (57.8% of total observations), and the highest percentage of larvae was recorded (69.4% of total larvae collected). The lowest frequency (1.83%) and the lowest percentage of larvae collected (0.33%) were recorded in a salinity of 4 g Cl/L (0.4%). It is interesting to note that during the surveys the authors encountered two larvae identified as superpictus: one larva was found in a collection from a rice field in Bahariya oasis (El Bawiti locality) where the pH of the water was 7 and the salinity was 0.75 g Cl/L. The other larva was collected from drainage water in a small channel in the New Valley (Bulaq locality) where the pH of water was 8.5 and the salinity was 1.4 g Cl/L. [An. superpictus is not a common anopheline in Egypt. It was first recorded by Kirkpatrick (1925), but later Halawani & Shawarby (1957) indicated that few specimens of this species were collected from Siwa oasis and Sinai – see more details below].

The third study was reported on by El Said & Kenawy (1982) dealing with the relationship between the pH and salinity of breeding waters and the larval density of four common anopheline species occurring in the same area of the previous studies. The data that have already been obtained were statistically analyzed using the least squares method. For sergentii analysis of data of the four study areas: Faiyum, Siwa oasis, Bahariya oasis, and the New Valley showed that there is a linear relationship between larval density and both pH and salinity. This relationship was represented by the equation:

\[ z = 7.66 + 0.02x - 1.39Y \]

where: \( z \) is the larval density, \( x \) is the pH value and \( Y \) is the salinity value. This indicated that:

- the density slightly increased as the pH increased towards alkalinity (slightly positive relation, + 0.02);
- there was a negative relation (-1.39) between larval density and salinity, i.e., the density decreased as salinity increased.

A further analysis of the data collected during larval surveys in the Nile Delta and other areas of Egypt was made by El Said, Kenawy & Gad (1983) to determine the species association of anophelines and culicines in the same type of breeding place. Analysis of data of four areas: Faiyum, Siwa oasis, Bahariya oases, and the New Valley showed that sergentii was encountered alone in 47.3% of the total positive collections of mosquito larvae. It was associated with 10 culicine species and four Anopheles species: pharoensis algeriensis, multicolor and superpictus. It was associated with pharoensis and multicolor in drains, surface and seepage waters, and pools, but only with pharoensis in irrigation channels and rice fields. Its association with algeriensis was recorded only in drains. In a rice field in Bahariya oasis, a single larva of superpictus (see above) was recorded together with larvae of sergentii. The other larval specimen of superpictus (see above) was found in association with culicine larvae in seepage water in the New Valley.

Gad & Salit (1972) reported the results of a mosquito survey carried out in the Red Sea area of Egypt. An. sergentii which is a desert species was collected for the first time by the second author from Wadi El-Ambag in the Red Sea area in 1962. Its larvae were found in abundance in slow moving waters of spring pools which had rocks and reeds at the edges. Its females were found in houses and tents. This area was resurveyed in 1969 and larvae of sergentii were found again in abundance, and two females and one male were collected from a room. The authors remarked that although sergentii was recorded from Faiyum, about 80 km from Minia governorate, and from Wadi El-Ambag about 150 km from Quena governorate, this species has not so far been able to establish itself anywhere in the Nile Valley.

Noting the above mentioned findings, Gad, El Said & Hassan (1984) decided to carry out ecological studies on sergentii in the Red Sea governorate. Larvae and pupae of this species were collected from a breeding place in the above mentioned locality, Wadi El-Amba which is situated at about 8 km west of the nearest group of houses in El-Qoseir town, on the periphery of El-Qoseir-Quena road. The breeding site was about 10 km east of the Red Sea coast. No other sources of natural surface water existed in this area. Potable water was transported to the locality weekly by ship or truck from Safaga which is located at 86 km from El-Qoseir. The inhabitants store freshwater in tanks on the roofs or in barrel in front of houses. Larvae of sergentii at different stages of development were obtained during March-July 1983 from a large water collection formed by a freshwater spring. The water from the spring passed through impermeable rocks and was found to contain low salinity (270-550 mg Cl/L) and had a pH of 7.5. The spring flowed into a large rocky
basin-like depression forming a pool. The pool contained slow moving water which was clear and shallow near the source, but stagnated within 50 m. Thick growth of vegetation such as water weeds, grasses and algae were encountered in this breeding place, and larvae of sergentii were present underneath vegetation and algal filaments near the edges of the breeding place. The climate in this area is subtropical, arid with warm summers (17-34°C) and relatively mild winters (14-23°C) with occasional rainfall in mountains in winter. Precipitation throughout the year is less than 50 mm. An. sergentii was common during late autumn, winter and spring when the water temperature ranged between 15 and 20°C in daytime. Larval density reached a minimum during summer.

Recently, a more extensive mosquito survey in the Red Sea governorate was reported by Gad et al. (1987). The survey was carried out in the western coastal area of the Red Sea, besides which three localities situated in the mountainous area of the eastern desert were surveyed. Each locality was visited at least once in every season throughout 1981-1983. Most of the mosquito specimens were collected as larvae or pupae, but in a few instances adult females were captured while attempting to feed on a human host. The only place where sergentii was encountered as larvae associated with culicines was the breeding place at El-Ambag during the winter and spring season, where more detailed observations on this species were conducted as mentioned above.

In Sinai, several mosquito surveys have been carried out in the past as well as more recently and a number of anopheline and culicine species have been recorded. Early records by Kirkpatrick (1925) showed the presence of sergentii at Ain Musa breeding in a slow moving grassy stream formed by the overflow of one of the springs, while superpictus was present at Kossaaima, breeding in a fast-flowing small drain, in which the salinity was about 0.5%. Salem (1938) collected larvae of sergentii in good numbers from Ain Eadeis in July 1935, but in August-September 1937 the larvae of this species was very scanty and their place was taken by superpictus and turkhudi. From Ain Gedeirat near Kossaaima, the same author collected larvae of superpictus in stagnant water collections from the spring near a narrow fast channel. It is useful to note that the same author described a new species hitherto named Anopheles aegypti nov. sp. [named later Anopheles rhodesiensis rupicolus Lewis]; the eggs of this species were found in a small collection of freshwater in Wadi Taba.

Abdel-Malek (1956) found both superpictus and sergentii breeding in association in a slow flowing stream fed from Ain Gedeirat, having thick growth of floating algae.

Gad & Darwash (1957) recorded sergentii breeding in streams fed from a spring at El-Tor in 1951 but when the same breeding places were visited in 1955, they were found to be free of mosquito larvae.

Gad et al. (1964) reported on a malaria (entomological/parasitological) survey carried out in Sinai during August-September 1962. In the southern region of Sinai, sergentii was found breeding at El-Deesa swamp which was situated at a distance of 4 km from El-Tor locality very close to the seashore. This place was surveyed previously in 1951 when no sergentii larvae were encountered, but multicolor and a few d’thali were present, and again in 1955, when only multicolor larvae were recorded. Adults of sergentii (43 females and one male) were collected from houses at El-Wadi, a locality situated at 1 km from El-Deesa breeding place. An. multicolor was the associating species in El-Deesa swamp, and its adults were also collected from houses at El-Wadi locality. Other sergentii breeding places were found near El-Tor in the vicinity of Hammam Musa springs. These springs were shallow and moved in twisted narrow channels in which vegetation and algae were abundant. Of three springs examined, only one was positive for sergentii larvae. A third locality where sergentii was found breeding was Wadi Feiran oasis. In this small oasis, many anopheline species including sergentii were found breeding in a small spring. The oasis is situated at about 50 km from St Katherine Convent and was usually used as a rest house by visitors travelling to the Convent. In the northern region of Sinai, sergentii was found breeding only in Ain Gedeirat, near Kossaaima in an uninhabited area with no houses nearby. Its larvae were abundantly present in the shady part of a spring which flows for about 6 km in a hilly region with many caves at the sides. These caves were high up and inaccessible, therefore could not be inspected. In a deserted hut near the spring an unfed newly emerged female of sergentii was collected. With regard to superpictus in Sinai, the authors cited the records of Kirkpatrick (1925) from Kossaaima, Salem (1938) and Abdel-Malek (1956) from Ain Gedeirat, hence it was considered that the distribution of superpictus was localized in Sinai.
During a faunistic survey of the inland water sources of Sinai carried out during 1968-1970, mosquito species encountered were recorded and reported on by Margalit & Tahori (1973). The authors summarized the previous records of mosquito species recorded in Sinai (see above) and added the records obtained from this survey. *An. sergentii* was found mainly on the western and eastern slopes of the southern mountain range and also in the coastal area. Its larvae were collected in waters having a wide chlorine range, from 23 mg/l at Bir Arbeein to 4700 mg/l at Wadi Sudar. *An. sergentii* was found breeding in association with several culicine species, and seven *Anopheles* species: *d’thali* (3 times), *hispaniola* (3 times), *multicolor* (twice), *superpictus* (once), *rhodesiensis rupicolas* (3 times), and *turkhudi* (twice). *An. sergentii* was suspected of being the major vector of malaria in southern Sinai. *An. superpictus* was found in Wadi Isla at altitudes up to 800 m. It was much less abundant than *sergentii*. *An. superpictus* was found breeding in association with two culicine species, and five *Anopheles* species: *hispaniola* (once), *multicolor* (once) *sergentii* (once), *rhodesiensis rupicolas* (once), and *turkhudi* (once). *An. superpictus* was one of the suspected malaria vectors in Sinai. The results of parasitological surveys carried out in Sinai by these authors and previously by Gad et al. (1964) are shown below under Subsection (ii) EPIDEMIOLOGY AND CONTROL OF MALARIA (para 1).

In Jordan, Farid (1954) in his article on the failure of DDT house spraying to interrupt malaria transmission in the Jordan Valley, pointed out that *superpictus* and *sergentii* were considered the main vectors of malaria. Both species were found to breed extensively in the vast breeding places along the banks of the Jordan river and its tributaries. In many instances both species were found in association in the same breeding place. Shallow water, running slowly over pebbly or rocky beds with scattered small vegetation and exposed to the sun, offered the best breeding conditions for both species. *An. sergentii* was also found breeding along the grassy edges of small streams and springs. In one instance, *sergentii* larvae were collected from an exposed well 5 m in diameter and about 30 m deep, containing some floating dead weeds. Both species were recorded in every village in the Jordan Valley. Surveys of DDT-sprayed premises for adult mosquitoes showed that *superpictus* and *sergentii* disappeared from the indoor resting shelters, but larval catches indicated that considerable breeding continued in nearby breeding places.

In Israel, Saliternik (1955) made a detailed review of the bionomics of *sergentii* and response to DDT spraying using a special trap and in comparison with *superpictus* and *sacharovi*. Observations on the optimal breeding sites showed that *sergentii* was breeding alone in 124 places and in association with *superpictus* and *sacharovi* in 39 places. The most favourable breeding conditions for *sergentii* were:

- shallow waters formed along stream beds and shallow puddles cut off from the main stream having a water depth below 15 cm; gentle flow over gravel bottoms; and shaded canals with vertical banks.
- optimal water temperature between 23 and 28°C.
- pH from 7 to 7.55.
- because of the small volume of water frequently utilized as a breeding place by *sergentii*, and as the amount of evaporation was large, salinity was as high as 0.6-0.7.
- owing to the temporary nature of the breeding places of *sergentii*, a fixed or typical flora was lacking. In unshaded places and in the presence of *Cladophora* and other filamentous algae, *sergentii* was found breeding in association with *superpictus*, and if *Myriophyllum* or *Ceratophyllum* flora were present, it was associated with *sacharovi*.

Barkai & Saliternik (1968) studied the breeding of anopheline mosquitoes in Israel during 1963-1965 at the last stages of the malaria eradication programme. The breeding places were classified into four types each of which was considered a different biotope.

Type A: springs, leakages of irrigation systems and seepages; and

Type B: natural streams, wadis and irrigation channels were favoured by *sergentii* and *superpictus*. Type A usually have clear, semi-stagnant water, and vegetation, if present, is usually low. Type B are breeding places which have running water and often bordered by vertical vegetation.
Salizernik (1967) updated his review of the bionomics of sergentii adding more information from observations carried out in Israel during 1961-1965. An. sergentii was found to breed throughout the year, with a maximum in October-November (55.57%) and a minimum in January-March (1.7%), mostly in seepages and leakages. With one exception - the Dead Sea - breeding of sergentii was also observed during winter months. Some explanations of this phenomenon were offered as follows:

(a) Rain (only about 55 mm annually) during winter months of December-February, tends to accumulate in numerous small pools and reduce the chloride contents existing in these small water collections.

(b) Unlike other places in the country, the low rain did not wash away the larvae from their breeding places.

(c) Water temperature in winter is about 24°C, which is the optimum breeding temperature for sergentii.

Intense breeding of sergentii was also found near settlements that were regularly sprayed with DDT for many years, because of the exophilic behaviour of this species. Despite intensive breeding, adults of sergentii could hardly be found in sprayed houses and stables. They could only be found in large numbers in a few caves. - see more details under 2.6/2.7 below.

In his review of the distribution and bionomics of malaria vectors in Israel, Salizernik (1974) summarized and updated the information on sergentii and superpictus. Both species are most abundant and distributed all over the country. They have the same breeding places: streams, wadis, canals, seepages and leakages. An. superpictus prefers sunlight with floating algae, and even breeds in rapidly moving waters, while sergentii tends to breed in more shallow, partially shaded, semi-stagnant water accumulations, especially under pebbles, and in seepages. Breeding of both species was controlled by alternating stream flow direction, periodical drying up of the stream beds, introduction of Gambusia affinis into streams, drainage work, DDT house spraying and larviciding operations. At present, the densities of both species have greatly declined for the following reasons:

(a) almost all natural streams have been polluted by sewage, thus rendered unsuitable for breeding anophelines.

(b) almost all breeding now takes place in small artificial water accumulations with limited water surfaces, which dry up periodically.

Recently, Pener & Kitron (1985b) analyzed the frequency of anopheline species collected as larvae during 1974-1983 in northern Israel. An. superpictus and sergentii which were often found in association, together constituted 50% of all anopheline larvae collected in most years. The relative frequencies of the two species showed significant negative correlation, \( r = -0.668, < P 0.05 \).

In Lebanon, Gramiccia (1953) as mentioned above described the breeding habitat of major and suspected vectors in the country. An. superpictus was found to favour running water among pebbles, banks of rivers, irrigation canals with vertical vegetation and irrigation basins. An. sergentii in its limited distribution in Lebanon, preferred small water courses covered with vegetation and swampy patches at the sides of rivers.

In Syria, Abdel- Malek (1958) found that superpictus ranks next to sacharovi in the northern part of the country. Larvae of superpictus were collected from slow moving sun-lit mountain streams having clear water running over pebbles with or without green algae, neglected irrigation canals with emergent and horizontal vegetation, rice fields and open parts of swamps. Larvae were also encountered in small water collections such as hoof-prlnts. Larvae of superpictus were associated with claviger in a shallow sun-lit pit situated on a hill and having green algae. In several villages in Derik, Kamichlieh, Hasseche, Deir-el-Zor, Tell-Abiad and Ain-el-Arab in the northeastern part of Syria, superpictus larvae were found either alone or in association with sacharovi larvae. In only two villages in Hasseche and Deir-el-Zor, superpictus larvae were found breeding in association with larvae of sacharovi and pulcherrimus.
2.3 Swarming and mating

Farid (1956) indicated that his attempt in 1939 to breed sergentii in captivity in Egypt failed, even when the dimensions of the cage reached 3 x 2 x 2 m. Swarms of sergentii were observed in Dakhla oasis in the western desert of Egypt during 1944, which were formed at dusk as well as before sunrise over mounds of earth 10–20 m high. Nuptial flights of this species appeared to extend for some kilometers. Some laboratory observations were made on adults of sergentii raised from larvae of this species collected during surveys of the Red Sea governorate, Egypt by Gad, El Said & Hassan (1984 – see under 2.2 above). Adult progeny were kept in cages and supplied with 10% sucrose, and human blood was offered on which the females fed readily to repletion under dark and light conditions. No swarming was observed. Three and four days after the bloodmeal, more than 500 eggs were laid, of which 150 hatched. Several females oviposited unfertilized eggs. Trials to establish a colony failed. These observations led the authors to assume that sergentii populations in the Red Sea area may consist of stenogamous and eurygamous subpopulations. In contrast, populations of sergentii from Fayyum governorate and Siwa oasis in the western desert proved to be eurygamous which necessitated applying artificial mating techniques in order to raise a laboratory colony – [see Beier et al. (1986) in VOL. I, under 2.1.4, p. 67. The only successful attempt to raise a self-perpetuating colony of sergentii was made by Prof. G. Davidson from egg batches of this species sent from Jordan in 1967, as cited by Zahar, 1974.]

No field observations on swarming and mating of superpictus could be traced.

2.4 Dispersal

In Egypt, Abdel-Malek & Abdel-Aal (1966) carried out a mark/release/recapture experiment during September–October 1965 in Siwa oasis of the western desert to investigate the dispersal of sergentii. Larvae of the 3rd and early 4th instars of sergentii were collected from two springs in Siwa, and bred in radioactive solutions. Two radioisotopes were used: $^{32}$P and $^{35}$S, and recaptured mosquitos were recognized by autoradiography. The isotope present in each recaptured specimen was identified by visual discrimination between high and low energy beta particles in the X-ray film: $^{32}$P producing diffuse fogging, while $^{35}$S gave a well-defined image. Routine capture stations were established within a circle of 2 km radius. Releases were made either from the centre or near the periphery of the experimental area, so that recaptures were possible up to a distance of 3.75 km in one direction. Out of 4260 labelled sergentii released, 37 were recaptured giving a recapture rate of 0.87%. The results showed that the males dispersed up to 3.4 km, and the females up to 2.5 km from the points of release.

In Israel, Salternik (1974) indicated that the flight range of both superpictus and sergentii does not exceed 2-3 km in summer, but in the autumn adults of sergentii were found at a distance of 6.5 km from their breeding place in the Dead Sea area, citing Shapiro, Salternik & Belferman (1944). [These authors marking mosquitos with gold dust (a bronze preparation finely powdered) recovered one marked sergentii female at a distance of about 4.2 km from the place of release in November, 1942.]

In Lebanon, Garrett-Jones (1957) carried out observations in two hill villages to investigate the migratory flight activities of superpictus and sergentii. The two villages were Deddё and Deir Bille, both in Koura country, not far from the Lebanese town of Tripoli. Deddё is situated at an altitude of 300 m and Deir Bille at 800 m. Very careful larval searches in the available waters were made around both villages to a distance of 1 1/2 km in the case of Deir Bille and 3 km in the case of Deddё. This was repeated on several occasions, particularly in late summer when anopheline mosquitos were caught from houses. At that time, no actual or potential surface breeding place was found within these distances. In early summer, each village contained a surface pond which later dried out; repeated searches failed to reveal anopheline larvae in these ponds. During 1953, while the entomological surveys were in progress, some "wells" (these were described as not being true wells but were underground rainwater reservoirs, excavated into limestone rock and usually lined with cement) were experimentally treated with DDT, HCH and other insecticides, and groups of village houses were sprayed to ascertain the absence of any house-resting claviger. The anophelines captured were all from untreated premises. At Deddё, superpictus was not found in houses between January and September, but eight females were collected in buildings in October and further specimens were found during
November-December 1953. At Deir Bille, several females of *superpictus* were found in a stable in March, but none was encountered in the following three months. In July, the species reappeared and became more frequent in October. No males were collected from either village. The author excluded the possibility that *superpictus* visited the two villages to feed, because men and cattle were available much closer to the local breeding places of this species. It would seem, though, that these observations indicate migratory flights. Regarding *sergentii*, its seasonal prevalence in Lebanon was from late July to November only. At other seasons no adults were ever collected, and larvae could not be detected even after very thorough searches in the breeding places. In October, two females were taken in houses in Deddâ in association with *superpictus* females referred to above. The author considered that *sergentii* females must have covered a distance of not less than 3 km in search, not of adult hibernation quarters, but of a fresh breeding place.

2.5 Local spatial and seasonal distribution

In continental Europe where malaria has been eradicated, *superpictus* in countries where it exists remains as a potential vector.

In Italy, a cytogenetic investigation was carried out by Sabatini, Coluzzi & Boccoli (1989 - in press) on samples of *superpictus* collected from the southern part of the country. An abstract of this study reads as follows:

"Polytene chromosome studies were carried out on various population samples of *An. superpictus* from different localities in Southern Italy. More than 7,000 female specimens, mostly obtained from daytime collections of indoor resting mosquitoes, were successfully scored for nurse cell polytene chromosomes. Night biting samples were also examined in some localities. Only one chromosomal polymorphism, due to a paracentric inversion involving the central third of the 2L arm, was recorded in all samples. In all localities, the inverted 2La arrangement showed remarkably stable frequencies although the populations examined were isolated from each other and at least some of them have presumably been subject to bottleneck in recent years because of insecticide treatments or ecological changes affecting the availability of breeding places. Departures from the Hardy-Weinberg expectations, indicating an excess of heterokaryotypes, were noted and critically analysed by comparing samples obtained simultaneously in the same locality from different cow sheds, from different sections of the same cow shed and from night and day catches in the same cow shed. The phenomenon was not found uniformly distributed among indoor resting samples: significant departures from the Hardy-Weinberg expectations were observed in some cow sheds but not in others situated nearby or even adjacent to them. These results did not support the hypothesis that the excess of heterokaryotypes was due to their greater longevity or to differential mortality in the preimaginal stages. It is suggested that different karyotypes may react differently to microclimatic specific conditions, since the Hardy-Weinberg disequilibrium was mostly observed in samples from resting sites that were more lit and subject to wider climatic variation."

As shown in document VBC/90.1-MAL/90.1 - under SECTION II, 2.1.3, *sergentii* was recorded for the first time in a small focus on the island of Pantelleria, Sicily by D'Alessandro & Sacci (1967) during an epidemiological investigation carried out during October 1967 on two indigenous malaria cases. The larvae showed some differences in the abdominal tergal plates and the pigmentation of the head from those observed in larvae of *sergentii* from other geographical areas. But careful examination of all other characters and the adult characteristics confirmed the identification of *sergentii*. The strain of Pantelleria, therefore, provides interesting material for further studies on the variability of *sergentii*. This species has never existed in the Italian territory and this confirmed record from Pantelleria represents the northernmost limit of its distribution, with the exception of a single historical record from Bulgaria (as mentioned under 2.1 above), where Dimitchev et al. (1962) listed *sergentii* and *superpictus* among the Bulgarian anopheline fauna studied since 1907 in addition to members of the *An. maculipennis* complex (see 1.5 above) but no details of the distribution of the two species were given by Dimitchev et al. (loc.cit.). These authors gave the results of their survey carried out during 1956-1958 in the Bulgarian littoral of the Danube where the species composition of members of the *An. maculipennis* complex was shown, besides which *hyrcanus*, *pseudopictus* and *claviger* were recorded, but no mention was made to either *sergentii* or *superpictus*.

1. The abstract was provided in advance through the kind cooperation of Dr A. Sabatini (personal communication, November 1989).
In Yugoslavia, superpictus as one of the potential vectors of malaria in addition to members of the An. maculipennis complex was recorded from indoor-resting collections in several areas: southeast Serbia (Adamović, 1979b); Neretva Delta (Adamović, 1983a); the plain of Skadar lake, Montenegro (Adamović, 1984); and Ravni Kotari (Adamović, 1985).

In the USSR, as shown by Artemiev (1980) superpictus is common in the mountainous areas of Central Asia and it also occurs in the Caucasus, and occasionally on the southern coast of the Crimea. In Central Asia, it is found up to 2300 m altitude in the mountains. On its seasonal distribution, superpictus hibernates in the adult stage. Massive dispersion of pre-hibernating (diapausing) females usually occurs in October. They hibernate in stables sheltering animal hosts and they feed on blood all winter except during very cold weather. Hibernating females move out of the winter shelters in March or April. In the spring and the first half of summer, the density of superpictus is low, because water bodies suitable for breeding are scarce at that time, with river beds being filled with water flowing from the mountains, and shallow water in gravel-covered river beds is almost non-existent. As the water level in rivers recedes in mid-summer, the river beds get drier and numerous breeding places suitable for superpictus are formed. The density of this species then begins to increase progressively to reach a maximum in October. Unfavourable years for superpictus are those in which the water level in mountain rivers becomes sufficiently high with summer rains to destroy all suitable breeding places of this species. Also unfavourable years are those which are dry when the water level in river beds decreases sharply and breeding places of superpictus dry up. It is only in those years when the water in mountain rivers remains at a moderate level, that the density of superpictus attains its maximum. Thus, the density of this species is subject to great fluctuations from year to year depending on the meteorological conditions. This in turn causes variation in the epidemiological significance of superpictus causing marked variation in the intensity of malaria transmission. An. superpictus is one of the potential malaria vectors in the USSR and is the most dangerous in the mountainous and foothill areas in Central Asia. It can be readily infected by F. vivax and F. falciparum. Its epidemiological importance being subject to fluctuations in its density in different years, has contributed to the appearance of sudden and large outbreaks of malaria in areas previously considered free from the disease.

In Turkey, superpictus is widely distributed occurring in areas at sea level to over 1700 m altitude. As shown by Postiglione, Tahanli & Ramsdale (1973), superpictus is an important vector in Turkey ranking next to sacharovi. Because of their different breeding habitats, the two species do not have identical geographical or seasonal distributions, but wherever they occur in one area they supplement each other. As superpictus exhibits zoophilic tendencies, its vectorial importance varies according to local conditions, and it also exists in many non-malarious areas. However, it was responsible for maintaining malaria transmission for many years in certain Mediterranean and Egean coastal regions, despite regular DDT house spraying. Because of density fluctuations due to variable breeding conditions, its vectorial importance varies between years. It hibernates in the adult stage sheltering in houses or in outdoor shelters.

In Morocco, Guy & Holstein (1968) indicated that sergentii exists in the whole country practically except in the mountainous regions situated above 1500-1600 m altitude. This species which had been considered predominant in the Marrakesh region, is in fact widely distributed, sometimes existing in abundance as in the south of Casablanca in the Atlantic zone and extending to the foothills of Rif in a region under the Mediterranean influence. Thus, the description of sergentii as a pre-Saharan species is no longer valid even though its original foci in Morocco were found in the Sahara. On the contrary, it exists outside the desert in competition with labranchiae, although the ecological conditions are not optimal for its survival. Hence, the role of sergentii in malaria transmission in the extreme range of its distribution is probably much reduced.

Previously, Guy (1963) pointed out that the role of sergentii in southern Morocco is similar to the role of labranchiae in the northern part, but it was difficult to determine the exact role of sergentii when it was associated with labranchiae in the south, or with d'thalii as a suspected vector in a limited area south of the Haut-Atlas. The seasonal prevalence of sergentii is more delayed than that of labranchiae, since the former does not appear in appreciable densities until June or mostly July attaining its maximum density in September-November. This phenomenon could explain why malaria transmission in Tafilalet was more retarded than in the rest of the country. Maps were presented month by month
showing the extent of distribution of *sergentii* in Morocco in association with either *labranchiae* or *hispaniola* or with both. The foci of *sergentii* situated north or south of the Haut-Atlas appeared to be present continuously from July to November. In fact, the Haut-Atlas seems to represent a strong geographical barrier that probably prevents the interchange between the north and south populations of *sergentii*. This was confirmed by the results of precipitin tests (see under 2.9 below) and by the exclusive presence of *d'halii* south of this mountain chain, a species which has the same biological characteristics as those of *sergentii*.

In Algeria, Senevet, Andarelli & Rehm (1960) referred to the distribution of *sergentii* shown by Senevet & Andarelli (1956) as being the southern territory (Sahara): M'chouméche (Aurès) and Bou Saada (Haut Plateaux). In October 1959, the authors discovered two new points where they collected larvae of *sergentii* both of which were in the Oran region close to the borders of Morocco: one point was situated at a latitude of 35°08' near Beni Saf; the other was situated at 2.5 km southeast of the former.

Holstein et al. (1970) in their presentation of lists and a map of the distribution of the anopheline species in Algeria, added the records which they collected from Hoggar and Tassili areas in the south of the Algerian Sahara during 1968-1969. The distribution of *sergentii* was found to be more extensive than they thought. Many new localities for this species were discovered. It was the predominant species in Tassili in June and in October-November, while in the remaining areas of the Sahara, principally in Hoggar, it manifested itself as a species of the autumn, with the exception of some stations where it appeared in April-June. In the northwest, *sergentii* in Timimoun, El Golea and Beni-Ounif, is an autumnal species, the presence of which is rarely detectable for more than two months. In these regions, the water of the breeding places was mostly saline; freshwater breeding sites were rare. In the pre-Saharan regions, while *sergentii* was present abundantly in Biskra (in the northeast), it seems that it has disappeared from Ghadala-Ouargla-Touggourt-El Oued zone as regular searches in the last few years in this zone failed to demonstrate its presence. To the north of this zone, it was in the Tebessa region (Annaba wilaya) that *sergentii* was encountered in 1969. In 1970, its presence was confirmed northwest of Aurès wilaya at the level of Constantine, and the species appeared in the Mediterranean area partly in Bedjaia (west of Constantine) and partly in Kolea (west of Alger).

Zulueta & Ramsdale (1975) reported on an entomological/parasitological survey for malaria carried out in the Saharan region of Algeria. Most observations were made in the Hoggar zone (Tamanrasset in Tamanrasset wilaya) and Tassili zone (Djanet, Ouargla wilaya). These zones have provided limited information in the past few years, although they had been subjected to several epidemiological studies for malaria in the past. Larval searches revealed the presence of *sergentii* associated with *d'halii* in irrigation canals at Abalessa, or alone in springs at Djanet, and in wells in Idelès. In the last two localities, irrigation canals were negative for all anopheline larvae due to the presence of *Gambusia*. In Ghadala, only *multicolor* larvae were recovered from streams. Search for adult mosquitos in 30 houses in six localities were negative despite the presence of larvae in the breeding places even in localities which were positive for larvae of *sergentii* (Abalessa and Djanet) as shown above. Likewise, direct man-bait capture outdoors conducted from 1730 to 1900 h was negative except for a few culicine mosquitos in two localities. In Théirit, *sergentii* larvae were found in irrigation canals, springs and streams, and all-night bait capture on a donkey yielded 48 *sergentii*, but unfortunately observations could not be pursued in this locality. The authors deduced that the absence of anophelines attacking man after sunset may indicate poor man/vector contact. Some remarks were made on the identity of *sergentii* as shown by the same authors below. Examination of 863 blood smears sampled from all age-groups including six infants at Silet, Abalessa, Djanet and Théirit were all negative for malaria parasites.

Ramsdale (1977) in October-November 1977 continued to investigate the water points along the line of the new trans-Saharan highway for recording the local anopheline species and assessing the risks of importation and establishment of the African vectors, An. *gambiae s.s.* and An. *arabiensis*. He collected some new records of the distribution of *sergentii*, *multicolor*, *hispaniola* and *d'halii*, and confirmed earlier records of anopheline distribution in the oases of the Algerian Sahara. A map was presented showing the available records of the anopheline species distribution along the national routes:
Ghardaïa-Aïn Guezzam, and Ouargla-Djanet. During a further mission Ramsdale (1978) pursued the assessment of the risks of persistence of malaria transmission in the Algerian oases through local or imported vectors and with a view to advising on the appropriate preventive or corrective measures. Many oases appeared to offer favourable conditions for breeding of *An. gambiae* s.s. and/or *An. arabiensis*, but no actual foci of the two vectors were encountered. On the other hand, *sergentii* was found to be more widely distributed than previously thought. A research project was suggested to ascertain the identity of the forms of this species existing in the Saharan oases (see below). A map was presented showing the latest records of anopheline distribution in the Hoggar region.

Ramsdale & Zulueta (1983) in their study of the implications of the trans-Saharan highway compiled the available records of the anopheline species in the northern and southern oases of Algeria, adding newer findings that were recorded subsequent to the mapped data of Holstein et al. (1970). These records are shown here in Tables 13(a) and (b), while Fig. 21 shows the location of various oases and the principal roads. These records clearly show that *sergentii* is more widespread in the southern oases. The authors pointed out that there are two forms of this species (citing Mattingly & Knight, 1956 and Gillies & de Meillon, 1968): one is *Anopheles sergentii sergentii* which occurs in the Asian part of the species distribution range, as well as in Africa north of the Sahara and in some Saharan oases; the other form is *Anopheles sergentii macmahoni* which occurs in East and West African savannas and penetrates into the Saharan oases. Separation of the two forms on morphological characters depends on delicate differences, often difficult to interpret (citing Rioux & Juminer, 1963), particularly in Algeria as some intergrading seems to occur. Regarding the vectorial importance, the two forms differ strikingly: *sergentii sergentii* has been recognized as an important malaria vector, whereas *sergentii macmahoni* has never been found biting man and is of no vectorial importance. This marked difference points to the presence of more than specific separation, despite the apparent intergrading. It is possible that *sergentii* and *macmahoni* are morphologically similar but biologically distinct species; the separation of the two may be difficult because of overlapping diagnostic characters. Alternatively, *sergentii* s.s. may include a complex of two or more species not separable by applying the existing morphological criteria.

Chauvet, Hassan & Izri (1985) also discussed the implications of the trans-Saharan highway on the malaria situation in the Maghreb and the Algerian oases of the Sahara. The Saharan species: *sergentii* and *multicolor* are regarded as inefficient vectors for transmission of tropical *P. falciparum*. Nevertheless, it must be kept in mind that in the past severe epidemics of *falciparum* malaria occurred as in the case of Djanet and Iberit oases in Tassili N'Ajjer where these two species exist. Road transportation will permit the colonization of new bodies of water and the Saharan oases by the two local vectors: *sergentii* and *multicolor* which are well adapted to the environment. The same suggestion shown above regarding the need for differentiation between the two forms of *sergentii* has been stressed.

The epidemiological consequences of the trans-Saharan highway including the importation of malaria and exotic vectors from Africa south of the Sahara as discussed by all the above authors are shown under Subsection (ii),2 below.

In Tunisia, Wernsdorfer (1973) in his assignment report indicated that in the southern region, particularly Médénine and Gabès governorates the malaria incidence was apparently reduced at the beginning of the 1960's, as a result of the control campaign against the desert locust, creating great insecticidal pressure on the local vector, *sergentii*, to the extent that it was eliminated from the majority of the zones or remained at a minimum density in others. This created a false impression in the minds of health authorities thinking that malaria was eliminated from south of Tunisia. This impression was dissipated when an analysis of the malaria situation in Gafsa showed that this region was not touched by the anti-locust campaign except at its periphery, leaving the bulk of the *sergentii* population unaffected. Consequently, malaria transmission continued in many foci with high transmission potential in others. Towards the end of the 1960's, *sergentii* began to spread and increase its local density in the south. In 1969, an important malaria focus was observed at Talalet, Médénine governorate, and in 1970-1971 very active foci were detected in two localities in Gafsa governorate: Foufi/Meloussi and Faid. Following the

1. Reproduced by permission of Mr C.D. Ramsdale and the Journal of Tropical Medicine and Hygiene from the article of Ramsdale & Zulueta (1983).
application of intensive control measures in the foci and their surroundings, the malaria incidence decreased in 1972. Nevertheless, there was one focus with 10 cases of P. falciparum that remained in an oasis outside the protected region.

In Libya, very little information is available on the bionomics of malaria vectors. Before the malaria eradication programme was started in 1960, Goodwin & Paltrinieri (1959) briefly described the malaria situation in Libya. Regarding the vectors, they considered sergentii and multicolor as the vectors of malaria in the oases of Libya; the latter was incriminated on epidemiological grounds (see under 4.5 below). While multicolor is widespread, sergentii has a more restrictive distribution. In certain oases of Tripolitania, the western province of Libya, hispaniola and superpictus were found, but only in moving waters. In the coastal areas, coustani and superpictus were the only vectors of non-oasis malaria in Libya. Goodwin (1961) compiled a list of anopheline

Table 13 (a). Anophelines recorded from the northern oases of Algeria.

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<tr>
<th>Northern oases</th>
<th>algeriensis</th>
<th>dhalai</th>
<th>hispaniola</th>
<th>labranchiae</th>
<th>multicolor</th>
<th>sergentii s.l.</th>
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*Newly recorded since review of Holstein et al. (1970).

Table 13 (b). Anophelines recorded from the southern oases of Algeria.

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<th>rhodesiensis</th>
<th>rupicola</th>
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<th>sergentii s.l.</th>
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*Newly recorded since review of Holstein et al. (1970)
Fig. 2. Maps of Algeria and (detail) the Hoggar showing the principal paved (unbroken lines) and unpaved (dotted lines) roads, international country borders (hyphenated lines) together with mean monthly rainfall (vertical bars) and temperature (line) from selected stations (US Department of Commerce 1967).
and culicine species recorded in Libya before 1957, and added the species he and the malaria staff recorded during 1957-1960. A map showed the distribution of certain anopheline species and culicine collection sites in the three regions of Libya: multicolor, sergentii, superpictus and hispaniola. The map showed that in Fezzan multicolor was widely distributed and sergentii was more restricted. Fewer records of multicolor were shown in Tripolitania and Cyrenaica where superpictus was recorded. While sporadic records of sergentii were shown in Tripolitania, none was found in Cyrenaica.

After the completion of the attack phase of the malaria eradication programme in Libya, malaria outbreaks occurred in certain localities of Fezzan province during 1964-1965, which necessitated the reinstitution of DDT house spraying on a focal basis. From a brief survey during July 1966 covering certain localities of Fezzan, Zahar (1966) compared the distribution of the anopheline species encountered with that recorded during the pre-eradication survey of 1958-1959. In Wadi El Adjal, sergentii and multicolor were encountered as adults and larvae, similar to the records of 1959, but in Gatroun multicolor was the only anopheine found as previously recorded in December 1958. Epidemiologically, the former valley was subjected to a malaria outbreak in 1964, while the latter, according to the available information escaped, even though constituting a border area exposed to an influx of immigrants from southern countries, namely Niger and Chad. This raised a question as to whether sergentii was solely responsible for the malaria outbreaks or it was joined by multicolor. Unfortunately, there were no entomological investigations during the outbreaks, at least on the anopheine species hitherto present. In the sprayed area of Wadi El Adjal sergentii and multicolor were found in appreciable numbers in unsprayed premises, but only a few specimens were obtained from sprayed premises. The possibility of outdoor resting of sergentii was not explored, but it was assumed that in such a hostile environment of hot and arid conditions in summer, the chances of finding suitable outdoor niches were remote. Thus, outdoor searches during the favourable season were recommended. In areas which have not been sprayed for several years, multicolor appeared in fairly high density, and the pattern of the blood digestion stages provided an indication of its endophilic tendency at least at the time of the survey in July. In Wadi Chatti, previous records from Brak showed the presence of multicolor only. The limited search made during July 1966 at Mahrouga spring 25 km from Brak showed that sergentii was present as well. A wider survey during the favourable season was suggested to delimit the extent of sergentii in this valley. No malaria cases were reported from this valley during 1964-1965 or even after the implementation of active case detection. This may have been due to the fact that this valley was not exposed to immigration as was the case in the other areas. There was a single record of superpictus from Tanhama, Wadi El Adjal in 1966. The July survey in this locality revealed the presence of sergentii as adult and larva, and multicolor as adult. It appeared that the identification of superpictus was based on a badly preserved single specimen. However, Shalaby (1972) who made a mosquito survey in Fezzan province during 1967-1968, reported that he found larvae of superpictus in Sebha and Gudoua during the cold season, November-December 1968. He collected a few eggs encountered in the same breeding place of the former locality. By rearing these eggs to the adult stage, three survivors were obtained which he identified as two males and one female superpictus. He cited previous records of superpictus in Fezzan province namely Ghidini (1935) who recorded this species from Borg Mezzem, El Ghatroun and Tejerhi, and Vermeil (1953) who recorded it from Seredeles. [Mr C. Ramsdale (personal communication, 1989) indicated that Vermeil (1953) made no reference to superpictus in Fezzan and considered that its particular larval ecology must make it very rare Indeed. Ramsdale who made several visits to the oases of Libya and Algeria doubts the presence of superpictus in that region].

In a recent review of the anopheline fauna of Libya, Ramsdale (1989 - in press) included records of species encountered during his advisory visits. A sketch map has been presented showing the different localities of Libya which is reproduced here as Fig. 32. Of the anopheines recorded previously in Fezzan, Anopheles rufipes broussesi, sergentii and multicolor remain to be present as indigenous species in this region. While An. rufipes broussesi appears to be restricted to the oases of Wadi Tanenzuft, sergentii and multicolor have a much wider distribution. These two species, for epidemiological reasons,
have been monitored over a period of some 15 years, during which their distribution has become increasingly circumscribed. In 1983, neither sergentii nor multicolor could be found in any of the oases of Wadi Etba and Wadi El Adjal, where they formerly had existed. The two species, however, still exist in Wadi Chatl, Hon-Wedden and Meduin-Zella group of oases, and sergentii is still a common mosquito in Wadi Tanezuft. There are three old records of superpictus from Fezzan which could not be substantiated and may have been due to misidentification of aberrant forms of Anopheles cinereus. This species is common in the contiguous oases of southern Algeria and elsewhere in the western desert.

In Egypt, Kirkpatrick (1925) indicated that sergentii was not found in the Delta or Nile Valley despite a very special search. He first recorded it at Ain Musa, Sinai (see under 2.2 above) and later at Fayed on the western shore of the Great Bitter Lake, and also in Fayyum and Kharga oasis. The only record of sergentii from the Nile Delta was at the desert fringe as reported by Farid (1940). In August 1939, a malaria epidemic broke out in two small villages on the former Royal Estate of Inshas, Sharqia province near the eastern edge of the Delta. Searches for anophelines revealed the presence of sergentii larvae breeding in a large drain and in seepage water around it at the two villages. Adults of sergentii were collected from houses of the two villages and from cattle and goat sheds. In the two villages, pharoensis, the main vector of malaria in the Delta, was comparatively rare at the time of the epidemic. The parasite rate in the human population ranged between 29.2% and 70.4% during August and November, with P. falciparum predominating and P. vivax constituting a much smaller proportion. Dissection of 220 sergentii females gave a sporozoite rate of 2.7%.

The seasonal prevalence of the Egyptian anophelines was studied by El Said et al. (1983) through longitudinal larval sampling. Larvae were collected by a net dipper measuring 15 cm in diameter for large breeding places, and a ladle of 10 cm diameter for smaller ones. Larval sampling was pursued from June 1978 to May 1979 at fortnightly intervals, making a total of 100 dips per capture station. For sergentii, the observations were limited to Fayyum governorate. Breeding of this species occurred throughout the year reaching a maximum in February and a minimum in November. Previously, Halawani & Shawarby (1957) indicated that sergentii breeds during September-May, i.e., the cooler period of the year, and breeding declines after May.

As mentioned above, superpictus was only found in negligible numbers in one of the oases in Egypt and has no epidemiological significance.

In Jordan, Farid (1956) showed that sergentii occurs in all the valleys that cut both plateaux east and west of the Jordan river and the Dead Sea, as well as in the Yarmuk-Jordan rift. It breeds all year round, but attains its maximum larval density between September and November. No hibernation was observed in sergentii, as it overwinters as larvae or as adults.

In Israel, Pener & Kitron (1985b) showed that both superpictus and sergentii are most common in the Jordan Valley, including Hula and the Sea of Galilee areas. While superpictus was the most common breeder in July-August, sergentii had a similar pattern but reached a peak later in September-November. Salternik (1974) indicated that while superpictus hibernates as an adult, sergentii does not enter diapause in winter, but its larvae develop slowly. The development time from oviposition to the adult stage was nine days in summer but was extended to three months during winter.

In Lebanon, Gramiccia (1953) indicated that sergentii is very rare and if in certain regions the associating principal vectors are controlled, it cannot stand alone as a vector, unlike the situation in Jordan. In contrast, superpictus according to Shidrawi (1959) is widely distributed all over Lebanon at altitudes ranging from sea level up to 1500 m altitude, unlike sacharovi which is confined to the plains. Both superpictus and sacharovi are regarded as the major vectors of malaria in Lebanon.

In Syria, the distribution of superpictus was described by Abdel-Malek (1958) from his surveys in 1953-1954 (see under 2.2 above). On the seasonal distribution, this author showed that superpictus similar to sacharovi increases its density from May to reach a peak in October, after which period, the density declines until March. In winter, its females are found in human habitation and stables in a state of hibernation. The surveys of Abdel-Malek were concentrated in the northern part of Syria where climatic conditions
Fig. 3. Sketchmap of Libya with enlarged representation of Fezzan province.
induced true hibernation, but this does not seem to be applicable to other parts of the country. Soliman (1961b) conducted observations on superpictus during December 1957-May 1958 in two distantly situated localities having contrasting climatic conditions in winter: Kasrieh (about 30 km northwest of Homs) in the central part of Syria, and Mehgar (about 60 km southwest of Deraa) in the southern part of the country. Measurement of temperature and relative humidity during November-April gave a mean of 7.5-12.7°C, with 58-82% RH at Kasrieh, and 10.8-23.9°C, with 69-88% RH at Mehgar. During this period, while larval searches were completely negative at Kasrieh, all larval instars of superpictus were present at Mehgar during winter months at a density of 24 larvae/10 dips in December 1957, and 16 and 11 dips in January and February 1958 respectively. Adult searches at Kasrieh yielded as many as 36 superpictus females/man-hour in each of January and February, 11 in March, and 5 in April, all of which had fat body. In contrast, the density of superpictus at Mehgar ranged from 5 to 9 females/man-hour during December-March. All of which were bloodfed. These observations clearly demonstrated that superpictus undergoes full hibernation under conditions of a cold winter as in Kasrieh, while it remains active during mild winter conditions as in Mehgar.

2.6 Resting behaviour & 2.7 Biting behaviour

In the USSR, Artemiev (1980) described superpictus as a thermophilic species and one that can resist dryness; hence, it is obviously endophilic. It has been found in abundance resting in buildings, particularly human dwellings and stables. This species is photophobic and invariably selects dark corners for resting. It feeds on both man and animals and prefers aggregations of hosts rather than individuals, and large-sized hosts to smaller ones. It feeds at dusk or during the night both indoors and outdoors. It can cover long distances in search of food. It is usually concentrated in human settlements, and it is very active and mobile when feeding.

In Turkey, Postiglione, Tabanli & Ramsdale (1973) showed that superpictus rests during the day in buildings mainly in stables, occupied or not. Nevertheless, it exhibited partial exophilic in both sprayed and unsprayed areas. It utilizes various types of outdoor resting shelters such as holes, crevices under banks or overhanging cliffs, rock cavities, caves, and nest holes. Exit traps operated in unsprayed premises showed a large exodus of superpictus females in all blood digestion stages. With exit traps operated in sprayed premises, mortality was high among females that made exodus into the traps indicating that superpictus females continued to enter buildings after spraying and were greatly affected by DDT. However, because of its exophilic tendencies, DDT spraying alone was insufficient to interrupt malaria transmission in areas of southern Turkey where superpictus was the sole vector. Collection of mosquitoes attacking human bait showed that superpictus will feed on man wherever he is located whether in open country or in villages, and is willing to enter houses to feed. Because animals are dispersed in the open in Turkish villages, superpictus feeds on man when its density is very high. However, certain groups of people, such as workers engaged in wood cutting and construction, as well as those working in farms or military camps and gypsies, who are not protected by the close proximity of animal herds, are much more susceptible to superpictus attacks as they constitute the main source of blood. Ramsdale & Haas (1978) further added that during traditional seasonal population movements [see Subsection (ii),1 below], families with their flocks spend the summer in tents similar to nomads invariably camping near waterpoints. In such situations, superpictus was able to maintain malaria transmission in southwestern Turkey in areas where sacharovi was absent.

In Morocco, Guy (1963) observed that when the night temperature inside houses exceeded 35°C, people slept outdoors. Careful searches showed that sergentii was biting people outdoors, but tended to rest indoors on tops of roofs where the temperature was quite low. Thus, sergentii was considered exophilic but endophilic in its resting habit. It was relatively more endophilic/exophilic when large numbers of animals were sheltered in stables inside the villages. This is why residual house spraying should be extended to cover the walls and covered ceilings of stables on a total coverage basis as in the inhabited rooms. Regarding the anthropophily of sergentii, precipitin tests run on bloodmeal smears taken from females collected in August 1961 at Zagora, Ourarzate province showed that 20.8% were positive for man. This confirmed the ability of sergentii to act as a vector south of the Atlas, unlike the situation in different localities north of this chain where only a single bloodmeal smear out of 485 showed a positive reaction for man.
No specific observations could be traced on the resting and biting behaviour of *sargentii* in Algeria or Tunisia. In Libya, Goodwin & Paltrinieri (1959) referred to the exophilic behaviour of *sargentii* observed in certain countries, but in Libya it was found resting indoors in daytime. In Egypt, information on the biting and resting behaviour of *sargentii* together with *phaeopsis* was obtained from Fayyum governorate by El Said et al. (1986) as shown under 3.6/3.7 below.

In Jordan, Farid (1956) described *sargentii* as an indiscriminate biter attacking man and animals both indoors and outdoors. It was collected during every hour of the night from the bare legs of bedouins sleeping in the open near their fields. The indoor-resting places were mostly found in shaded and dark corners in rooms or stables, as well as in fissures, holes or niches in walls. In areas with caves and fissures in the neighbouring hills, *sargentii* could be obtained in good numbers from these sites. In some instances, it was found in dark spaces underneath rocks, or in holes among these rocks. Females of *sargentii* seldom entered bell-type tents used as a trap as tried in Egypt, and although they were found attacking bedouins sleeping in their crude hair tents, they seldom remained inside after biting. They usually avoid light by changing their resting places during daytime in search for dark corners, such as folds of dark clothing, empty earthenware pottery jars, pigeon-holes, fissures or holes in walls. They were very rarely found in dense foliage, avoiding places with high humidity. To conclude, *sargentii* was described as a highly excitable mosquito, and any change in light intensity, or temperature and humidity irritates it and causes it to seek an appropriate resting site. Observations were made on *sargentii* in DDT sprayed premises in the Jordan Valley. Adults of this species showed marked avoidance of sprayed surfaces. Thus, the absence of *sargentii* adults from DDT sprayed premises does not necessarily reflect the effectiveness of house spraying. No follow-up observations by window traps fixed to DDT-sprayed premises could be made to obtain accurate information as to the number of adults of this species which enter [and leave] the sprayed premises, hence it is not known whether they remain for a sufficient time on sprayed walls to receive lethal doses of DDT. In fact, Farid (1954) in his report on the inability of DDT house spraying to interrupt malaria transmission in the Jordan Valley, concluded that the topography of the area with its weathered limestone hills flanking the valley, with its sub-tropical climate, together with the habits of the nomadic population, can have a bearing on the malaria problem by favouring local malaria vectors such as *sargentii*, and probably *superpictus*, enabling them to bite in the open and to find daytime-resting places in accessible caves and fissures in the nearby hills and so evade contact with DDT sprayed premises. Thus, a high rate of malaria transmission was maintained in the Jordan Valley, despite the DDT house spraying carried out in three successive years. Therefore, Farid advocated that in such areas, antilarval measures should resume their important role in the fight against these malaria vectors.

In Israel, Saliternik (1955) recapitulated previous observations which indicated that *sargentii* was caught biting man and domestic animals throughout the night and occasionally during the early evening, both indoors and outdoors. It was regarded as an avid biter during the autumn, and was considered both anthropophilic and zoophilic. From detailed observations on resting habits in both unsprayed and DDT sprayed areas, it was concluded that:

(a) *sargentii* was practically eliminated from sprayed houses;
(b) *sargentii* tended to seek unsprayed surfaces;
(c) small numbers of this species were found in open fields.

Saliternik (1967) carried out additional field investigations on the bionomics of *sargentii* during 1961-1965 aiming at enhancing vector control measures for malaria eradication in Israel. The main questions to be answered were: why *sargentii* concentrated in caves; why there was a high population density in the Dead Sea area also in winter; and why residual house spraying failed to interrupt malaria transmission. Neot Kikar farm was selected for field observations. It is a small isolated farm at the southern point of the Dead Sea, at 400 m below sea level. The area provides the most ideal conditions for *sargentii*: hot and dry climate; numerous suitable breeding places; sources for blood, i.e., man, animals. Moreover, the area is the only place in the country where caves and crevices in limestone hills provide natural resting places for *sargentii*. All buildings in Neot Kikar were sprayed at least twice annually with a 5% DDT emulsion at a dosage of 2 g/m², and all animals were sprayed regularly every 2-3 weeks with 1% Hexalan (a formulation of HCH). In a hill situated at 3 km north of Neot Kikar, a crevice was selected. Only occasional cattle were found in the vicinity. The crevice was 80 cm high at the entrance.
and several metres deep. After the rear end was cemented the depth was 1.5 m. Since
sergentii hide between stones and pebbles, often change their resting places because of
changes in temperature, humidity, light intensity and draft conditions in the surroundings,
collection of mosquitoes with an aspirator could not be made. Instead, the pyrethrum spray
sheet method was utilized covering the entrance also with a second sheet. Collections were
made once monthly, and from July 1961 to November 1963 a total of 2230 adults of sergentii
were collected. Records of temperature and relative humidity were obtained from inside and
outside the cave. Adults of sergentii were found throughout the year and there were large
fluctuations in its population. During the period of collection, the mean monthly
temperature inside the crevice was equal to the mean monthly temperature outside in the
shade, whereas the RH inside was higher in March-October and lower in November-February
than the mean monthly RH outside. These microclimatic conditions allowed the development
of the sporogonic cycle in sergentii females throughout the year. It was concluded that
the difference in humidity inside and outside is the determining factor for regulation of
population densities of sergentii. During winter months, sergentii was dispersed also in
various superficial holes and fissures of the limestone rocks, protected from the light and
wind. Data were also collected on the effect of the presence of animals in the vicinity of
the mosquito population inside the cave. The male population of sergentii was always high
(up to 85%). The presence of cattle at night in the vicinity increased the female
population in general, and those with fresh blood in particular. The numbers of those with
fresh blood were considerably reduced when cattle were recently sprayed (1-2 weeks
previously) with Hexalan. Further observations were made on the behaviour of sergentii in
sprayed and partially sprayed rooms. As summarized by Saliternik, these observations
showed:

(a) In the past, many sergentii adults used to be found inside human dwellings and in
animal sheds before DDT spraying was started in 1945. At present, they are rarely found
inside dwellings, even in the Beit-Shan area, where intensive breeding still continues and
DDT spraying was discontinued for the past six years.

(b) Some sergentii females feed on man in DDT sprayed rooms, but leave immediately
after biting. The irritability of DDT to sergentii was well marked, as the females were
observed to enter DDT sprayed rooms, bite man and then disappear. In one case, all
mosquitoes released (94 females) inside a closed empty room with two walls sprayed with DDT
(one month previously), received a lethal dose during the night, although only eight were
seen resting on DDT sprayed surfaces during the first hour after release.

(c) An. sergentii females were found to be exophilic and endophilic, biting both man
and animals, but with a more zoophilic tendency. Their concentration and fluctuation
depend on the availability of blood sources. Precipitin tests made on 88 bloodmeal smears
of sergentii collected from a cave near Neot-Kikar farm, not sprayed with DDT, were all
negative for man.

(d) No physiological resistance was detected in larvae of sergentii to DDT or
HCH/dieldrin [Later HCH/dieldrin resistance was recorded in sergentii in Jordan].

(e) In conclusion, the failure in interruption of malaria transmission in the initial
years of DDT spraying in Israel and Jordan was probably due to the exophilic habit of
sergentii. However, no indigenous malaria cases have been reported in Israel since 1964,
despite the continued intense breeding of sergentii. The possible explanations are:
malaria gametocyte carriers are absent in the breeding areas of sergentii; and indoor DDT
spraying for many years markedly reduced the contact between sergentii and man.

Saliternik (1974) summed up the available information on superpictus and sergentii in
Israel. The behaviour of the two species was similar: both feed and rest indoors and
outdoors as the females bite man and animals and use the same hiding and sheltering places,
including caves and fissures.

In Lebanon, Shidrawi (1959) described the behaviour of superpictus as being different
from that of sacharovi. An. superpictus was found to enter houses in the evening shortly
after sunset, and leaves early at dawn never rest indoors during daytime, although it was
sometimes found in stables. It was found resting in caves, tree holes, rock crevices and
other natural shelters. Therefore, the control of this species by DDT residual house
spraying was difficult, even though no DDT resistance was detected. However, a noticeable
degree of reduction in its density was observed.
In Syria, Abdel-Malek (1958) found that *superpictus* uses the same resting sites as *sacharovi*, including human habitations, animal shelters and stables where they rest in dark corners on spider webs, behind clothes and utensils hanging on walls, underside tables or inside large earthenware potteries used by the inhabitants for storing cereals. In addition, *superpictus* was caught resting outdoors away from human habitation; its adults were caught in November 1953 in caves in Rastan north of Homs, together with *claviger*. Also rocky caves around Hama were found to be favourable resting sites for adults of *superpictus*.

2.8 Sampling of mosquitoes in flight

In Morocco, a comparative study of different sampling techniques was carried out by Bailly-Choumara (1973b) (see under 1.8 above). The two non-Saharan stations at which *sergentii* was present were Marrakesh and Berkane, the captures were made during September 1968. The man-biting rate of *sergentii* indoors was as low as 1/bite/man/night in the two localities. Likewise, the indoor resting density was low ranging between 1.6 and 3.5 females/room. A higher man biting rate was recorded outdoors at Berkane reaching 4.2/man/night on an average. The normal CDC light trap in human habitation gave a poor yield ranging between 1.6-3.5 females/trap/night, but a much higher yield was obtained from the traps placed in stables reaching a maximum of 50 and 121/trap/night at Marrakesh and Berkane respectively. The light traps placed outdoors gave a maximum yield of 25/trap/night only at Marrakesh, but none was caught at Berkane in a single night. The proportion of unfed females of *sergentii* varied considerably according to the method and site of capture. While the normal CDC and UV traps placed in human habitation and animal shelters respectively gave comparable results (75% unfed), the normal CDC trap placed in animal shelters gave a much lower proportion (33%) as there was an excess of fed females (60%). The two types of traps placed outdoors gave 60% and 48% unfed females respectively while hand capture in outside shelters gave 36%. The parous rate of *sergentii* recorded at Marrakesh in collections of CDC traps indoors was 69% but the number of females dissected from man-bait capture indoors was too small to be considered (9). The parous rates recorded in samples of man-bait capture and CDC traps outdoors were not significantly different, 65% (31 dissected) and 43% (37 dissected) respectively. These results may indicate that the CDC trap can be a useful tool for collecting *sergentii* for dissections in conditions similar to those of Morocco, but more trials are needed in other areas of its distribution.

In Israel, Saliternik (1967) used light traps for sampling of *sergentii*. Using the New Jersey light trap, 115 *sergentii* were collected in 1955 from one locality in the Jordan valley and 102 were collected in 1956 from another locality in Beit-Shan valley. Using the CDC miniature light trap with dry ice during 1964-1965 at Neot Kikar farm, significant numbers of *sergentii* could be collected, and the relative density increased from July to October with the peak being pronounced in October.

2.9 Host feeding patterns

In Turkey, Postiglione, Tabanli & Ramsdale (1973) showed that precipitin tests and comparative baited net trapping confirmed that *superpictus* exhibits zoophilic tendencies as previously indicated by Livadas & Sphangos (1940) and from tests compiled by Bruce-Chwatt, Garrett-Jones & Weitz (1966). The observations in Turkey showed that cattle, sheep, goat and donkeys were more attractive to *superpictus* than man.

From the results of precipitin tests compiled by Bruce-Chwatt, Garrett-Jones & Weitz (loc.cit.) covering the period July 1959-July 1964 for *superpictus* and *sergentii* in countries of the Mediterranean Basin are shown in Table 14.1

1. Data reproduced by permission of Prof. L.J. Bruce-Chwatt from the paper of Bruce-Chwatt, Garrett-Jones & Weitz (1966) in the Bulletin of World Health Organization.
Table 14. Results of precipitin tests of bloodmeal smears of *sergentii* and *superpictus* in the Mediterranean Basin, 1959-1964.*

| Country | Species | Spray status | Resting biotope | No. smears | % +ve for primate blood
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordan</td>
<td><em>sergentii</em></td>
<td>N</td>
<td>0</td>
<td>16</td>
<td>(1)**</td>
</tr>
<tr>
<td>Morocco</td>
<td>N</td>
<td>H</td>
<td>82</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td><em>superpictus</em></td>
<td>N</td>
<td>0</td>
<td>439</td>
<td>0.7</td>
</tr>
<tr>
<td>Turkey</td>
<td>N</td>
<td>DDT</td>
<td>0</td>
<td>363</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>220</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Jordan</td>
<td>N</td>
<td>?</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Syria</td>
<td>N</td>
<td>H</td>
<td>0</td>
<td>93</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* See abbreviations in footnote of Table 9.
** Sample too small to be considered for percentage; number of positive smears in parentheses.

These results, however, may have been outdated through changes in the ecological conditions involving the man:animal ratio. More recent results of precipitin tests consolidated by Garrett-Jones, Boreham & Pant (1980) did not show data for *superpictus* from any geographical area. For *sergentii*, only a single record was given from Tunisia in 1971, where 45% of 53 bloodmeal smears collected from human dwellings were positive for man.

In Morocco, Guy (1963) (see under 2.5 above) indicated that in precipitin tests carried out on bloodmeal smears of *sergentii* collected from houses at Zagora, Quarzazate province in August 1961, 20.8% were positive for man, whereas only one smear was positive for man out of 435 smears collected from different localities north of the Atlas. This was taken to indicate the vectorial role of *sergentii* south of the Atlas, unlike the north.

In Egypt, a series of studies of host-feeding patterns of anopheline species has been carried out in recent years. Kenawy et al. (1986) reported the results of precipitin tests on bloodmeals of *sergentii* and *multicolor* collected from Siwa and Gara oases in the western desert. Gara is a small oasis, and at the time of the study domestic animals were donkeys, goats, sheep, one buffalo and many chickens, with animal sheds included in houses. Siwa is a large oasis and the same type of animals existed plus cattle, horses, camels, dogs, cats and geese with animal sheds separated from houses. Mosquitoes resting inside houses and animal sheds were sampled by space spraying using the index sheet method (see description under 3.5 below). Engorged females were placed in 1.5 ml plastic vials and frozen at −70°C until tested. Bloodmeals were identified by the modified precipitin test (described by Tempelis & Lofy, 1963). As can be expected, the highest proportion of man-positive bloodmeals of *sergentii* came from houses, 48% (54 tested), while 13% of the bloodmeals from animal sheds were positive for man (209 tested). At El Gara, the proportions of man-positive bloodmeals of *sergentii* from houses and animal sheds were 86% (21 tested) and 7% (126 tested) respectively. Of a total of 435 bloodmeals of *sergentii* collected from both Siwa and El Gara, 22% were positive for man. Only 62 bloodmeals of *multicolor* were tested (7 from houses at El Gara and 39 from animal sheds in Siwa and El Gara) of which 14% were positive for man. Most bloodmeals of the two species showing non-human origin were identified as sheep/goat and horse/donkey. The proportion of bloodmeals of *sergentii* from both Siwa and El Gara giving positive reaction for bovid was very low (1%). This was explained as probably being due to the low relative abundance of bovine hosts in the two oases. Reference was made to the only precipitin testing carried out previously on *sergentii* in Siwa by Barber & Rice (1937) recording a high proportion of bovid-positive bloodmeals.

[From the original publication of Barber & Rice (loc.cit.), of 47 bloodmeals *sergentii* collected from village houses or bedouin tents, only 3 (6.4%) were positive for man. Of the remaining bloodmeals, 28 were positive for cow, 13 for sheep and 3 for horse. From another village, all 36 bloodmeals of *sergentii* collected from stables were positive for cow, but very few people lived in this village at the time of collection.]

Further studies on host feeding patterns of *sergentii* in Egypt are included with those of *pharoensis* in Faiyum governorate under 3.9 below.
2.10 Longevity

The only information that could be traced concerns sergentii in comparison with two other species. This was part of the study of the anophelines of the Maghreb by Guy & Holstein (1968) to determine the vectorial role of three Anopheles species: hispaniola, sergentii and claviger. The authors emphasized that dissection of the salivary glands is the conventional method for incrimination of a species as a vector of malaria, but the statistical probability to find a sporozoite-positive among species of Africa north of the Sahara in which the sporozoite rate rarely exceeds 0.2-0.3% makes the reliability of the dissection method doubtful. Therefore, the authors resorted to determination of the physiological age by Polovodova's technique as a means for establishing the vectorial possibilities of these species. During 1966-1967, dissection of the ovaries was performed on samples of hispaniola from different regions in Morocco, sergentii from foci of malaria transmission, and claviger from mountainous regions in Algeria and Morocco. The results are compiled here in Table 15.1


<table>
<thead>
<tr>
<th>Species</th>
<th>Total dissected</th>
<th>% Nulliparous</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>% Parous</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>hispaniola</td>
<td>1226</td>
<td>66.5</td>
<td>20.2</td>
<td>12.6</td>
<td>0.48</td>
<td>0.22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>sergentii</td>
<td>423</td>
<td>45.3</td>
<td>17.0</td>
<td>18.9</td>
<td>2.1</td>
<td>9.3</td>
<td>3.0</td>
<td>2.1</td>
<td>2.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>claviger</td>
<td>140</td>
<td>62.1</td>
<td>13.6</td>
<td>10</td>
<td>5.7</td>
<td>7.9</td>
<td>0.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The duration of the gonotrophic cycle in hispaniola is unknown, but it could be estimated as being more than three days under the climatic conditions of Morocco; the first cycle probably takes four days and the subsequent cycles three days maximum. The authors pointing to the results of dissections, considered none of the hispaniola females can live sufficiently long for the sporogony cycle to be completed. Thus, hispaniola in the Maghreb cannot act as a natural vector for human malaria. The data of sergentii presents a different picture from that of hispaniola. Assuming that the duration of the gonotrophic cycle in sergentii is the same, 7.4% of the females of sergentii (5-parous + 6-parous + 7-parous) can support the development of the sporogonic cycle. With claviger only 0.7% of its females (5-parous) can allow the development of the sporogonic cycle. This poses a question as to the role of claviger as a potential vector; the corroborating epidemiological evidence indicates that in malarious localities claviger is found late in the season causing autumnal transmission when labranchiae manifests itself only for a short period. The authors underlined that the present results are preliminary and await further complementary studies involving adequate sample sizes. However, these initial results could serve as a guide for the entomological component of the epidemiological studies in the malaria eradication campaigns in North Africa.

Further data on age-grading of sergentii together with pharoensis were obtained in Egypt as shown under 3.10 below.

No information on age-composition of superpictus populations could be traced in the present geographical area. In the USSR, Detinova (1962) cited some studies carried out on age-grading of superpictus populations in Stalinabad, but no details were given.

2.11 Natural infection

Old records of oocyst and sporozoite rates of superpictus and sergentii are listed by Boyd (1949) citing the respective references. Of these historical records, some data related to superpictus have already been included under the An. maculipennis complex above (see 1.11).

1. Compiled by permission of Dr S. Bellazoug, Editor, Archives of Institut Pasteur d'Algérie, from the paper of Guy & Holstein (1968) - permission of Dr Guy or Dr Holstein could not be sought as their present addresses could not be traced.
Recently, Kasap et al. (1987) in Turkey succeeded in infecting experimentally a strain of superpictus from Adana with a local strain of P. vivax. Laboratory conditions under which the experiment was done (24°C and 80% RH) were thought to simulate natural conditions in the malaria endemic area of southeastern Anatolia. Thus, the experiments indicated that superpictus is an efficient laboratory vector, and should not be ignored in future entomological studies. The role of superpictus in Turkey is being obscured by that of sacharovi, wherever the two species exist. The authors, therefore, recommended that additional field and laboratory studies should be conducted to provide a better understanding of the respective role of the two vectors in Turkey (see information on sacharovi under 1.11 above).

Farid (1954) recorded one sporozoite-positive sample in a sample of 70 sergentii collected from a cave at Gurum village in DDT sprayed area in the Jordan Valley in 1952. Farid (1956) recalled his findings (Farid, 1940) of 2.7% sporozoite rate in sergentii during an epidemic of malaria that broke out in two villages in Sharkyia province in the Nile Delta, Egypt in 1939 (see under 2.5 above).

Salternik (1974) in Israel also recalled some old data of sporozoite rates that had been recorded in the past, citing several references: Kligler (1930) recording a sporozoite rate of 1.5% in superpictus (no. dissected not given), and 0.5% in sergentii (193 dissected) during January-December; Lumsden & Yoffe (1950) recording sporozoite rates of 0.2% in superpictus (539 dissected) and 0.3% in sergentii (744 dissected) during October-December.

A new record of sporozoite rate of sergentii was obtained from field studies conducted by El Said et al. (1986) in Faiyum governorate, Egypt, where pharoensis was simultaneously found with gland infection (see 3.11 below).

Recently, Shehata et al. (1989) attempted to detect P. falciparum and P. vivax sporozoites in sergentii and other anophelines collected from Siwa oasis and Faiyum governorate, Egypt, during 1983–1984, by applying the techniques of the immunoradiometric assay (IRMA) of Zavala et al. (1982)1 and enzyme linked immunosorbent assay (ELISA) of Burkot, Williams & Schneider (1984a)1 and Writz et al. (1985)1. Mosquitoes were collected from indoor day-time resting shelters and by man- and animal-baited traps outdoors. Mosquitoes were stored at -70°C until assays were performed during October–November 1986. A total of 573 mosquitoes were collected from Siwa oasis and Faiyum governorate (the two areas are known to be active foci of malaria in Egypt): 463 sergentii, 29 multicolor and 81 pharoensis. P. falciparum sporozoites were detected by both IRMA and ELISA in two specimens: one from Siwa oasis out of 389 tested (0.26%) and one from Faiyum governorate out of 74 tested (1.35%). Most of the mosquitoes tested were collected resting indoors. No P. vivax sporozoites were detected. All samples of multicolor and pharoensis were negative, but the sample size was too small to lead to valid conclusions. The authors considered their findings as representing the first incrimination of sergentii as the responsible vector of malaria in Siwa oasis, and at the same time confirm the findings of El Said et al. (1986) in Faiyum and Farid (1940) in Sharkyia province (see above). However, the sporozoites of P. falciparum detected by these assays in this investigation were not necessarily present inside the salivary glands of the tested specimens, because the extract of the whole Imosquito (head, thorax and abdomen) was used. This can give rise to an inflated sporozoite rate leading to erroneous epidemiological interpretations. For this reason, the authors regarded their findings as identifying sergentii as a potential malaria vector in Siwa oasis and Faiyum governorate. [This term potential should not apply to Faiyum where El Said et al. (1986) provided evidence indicating definite incrimination of sergentii from classical gland dissection, unless there have been doubts that the sporozoites found in the glands were not of human origin].

2.12 Vector resistance to insecticides

The recent status of resistance of sergentii and superpictus to insecticides is extracted from the tabulated data in the last two reports of the WHO Expert Committee of Insecticide Resistance (WHO, 1980 – TRS. No. 655, and WHO, 1986 – TRS. No. 737) as shown in Table 16.

1. See VOL. I, document VBC/88.5-MAP/88.2, under 2.9, pp. 171-181.
Table 16. Insecticide resistance in An. sergentii and An. superpictus in the Mediterranean Basin.

<table>
<thead>
<tr>
<th>Species</th>
<th>DDT</th>
<th>Dieldrin/HCH</th>
<th>OP/carbamate</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>sergentii</td>
<td>Egypt</td>
<td>Jordan</td>
<td>Jordan: temephos</td>
<td>-</td>
</tr>
<tr>
<td>superpictus</td>
<td>Afghanistan, USSR</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

No genetical or biochemical studies have so far been carried out on DDT resistance in the two species.

There is a record in TRS No. 737 showing temephos resistance in sergentii in Jordan, but recent tests carried out in Jordan showed that both sergentii and superpictus are susceptible to temephos. [see under Subsection (ii), 1 below].

In the list of species and countries where insecticide resistance has had epidemiological or economic impact and/or necessitated a change in control operations (in TRS. No. 737, 1986) DDT resistant sergentii in Egypt was included.1

More recent reports communicated to WHO during 1984-1988 did not include tests for sergentii in the present geographical area. Only a single test was reported in 1985 from Syria indicating that superpictus was susceptible to permethrin in the Aleppo area.

3. An. pharoensis

3.1 Vector importance

In its wide range of distribution, pharoensis acts as a principal vector of malaria only in the Delta and Nile Valley in Egypt (see SECTION II, under 2.1.4 and Fig. 4 in document VBC/90.1-MAL/90.1). It was only in the southern coastal plains of Israel that a small outbreak of malaria occurred in malaria-free settlements where pharoensis was detected and thought to have flown from Egypt through long-distance migratory flights (see 3.4 below).

3.2 Breeding habitat

In Egypt, Gad et al. (1982) who studied the characteristics of breeding habitat of anopheline species in different parts of the country, described the breeding places of pharoensis as being clear, stagnant and shallow waters especially those having a thick growth of vegetation. Shade is essential, and this is provided by plants growing in both breeding waters and at the edges of the breeding place; no record was obtained for breeding of pharoensis in sites exposed to direct sunlight. The types of breeding places encountered were:

- drains and irrigation channels having stagnant water as commonly seen in rice fields;
- surface water collectisons including seepages, pools and burrow-pits characterized by having vertical vegetation;
- rice plantations especially those situated near human dwellings and having small or moderately growing plants. In plots with high plants, larvae were concentrated mainly at the edges of the field;
- other cultlvations mainly those having sites with thick growth of "Sammar" (used for making mats).

Rice fields are the most favourable breeding places for pharoensis; the mean larval density in these fields ranged between 3.38 and 7.02 larvae/10 dips in the Nile Delta, Canal Zone, Faiyum and the New Valley.

1. Enquiry has been made to define the exact area in Egypt from which DDT resistance in sergentii was recorded.
In Faiyum governorate, Soliman, Rifaat & Ibrahim (1967) found *pharoensis* larvae breeding in pools overgrown with grasses, edges of lakes, swamps, seepages, burrow-pits as well as rice fields with moderately growing plants. In summer, the temperature of the breeding waters ranged from 21.1 to 36.6°C, and larvae avoided sites exposed to direct sunlight. The larvae were found mostly among clumps of reeds and grasses situated at the edge of the breeding places. Breeding waters contained 1.65 mg/l sodium chloride, and the pH was about 7.5. Larvae were abundant during June-December, but their numbers subsequently decreased from January to reach a minimum in February-March.

As mentioned under 2.2 above, El Said et al. (1982) determined the chemical characteristics of breeding waters of anopheline species occurring in Egypt. The data of five anopheline species including *pharoensis* were presented. Based on this, it was concluded that:

- *pharoensis*, *sergentii*, *superpictus*, *algeriensis* and *tenebrosus* are freshwater breeders (the range of salinity level for *pharoensis* was 0.05-5.0 g Cl/l, or 0.005-5.0%);

- *multicolor* is an indiscriminate breeder, found in fresh and brackish water (salinity range of 0.2-21.25 g Cl/l or 0.02-2.125%).

Previously Kirkpatrick (1925) found that 89.8% of *pharoensis* larval samples were collected from waters having less than 0.2% salt and the remaining samples were obtained from water having 0.21-1.5% salt. The data for *multicolor* given by the same author were: 18.2% of the samples were from water with up to 0.2% salt, 73.4% from 0.21-3.0% salt, and 8.4% from 3.1 to 6.0% salt, i.e., *multicolor* can tolerate much higher salinity than that recorded by El Said et al. (1982).

The study of the relationship between the pH and salinity of the breeding waters and the larval density of Egyptian anophelines by El Said & Kenawy (1982) showed that the larval density of *sergentii* increases as the alkalinity increases, but it showed an inverse relationship with salinity (see 2.2 above). The larval density of *pharoensis* was found to be higher in breeding places which have a high pH value and lower salinity. With *multicolor* there was a negative relationship between larval density and pH value. This species can breed in waters with high salinity that cannot be tolerated by other Egyptian anophelines.

In the study of El Said, Kenawy & Gad (1983) on species association of Egyptian anophelines in breeding places, *pharoensis* was encountered 390 times in the Nile Delta, of which it was recorded alone 70 times (18%). It was mostly associated with one anopheline species (*tenebrosus*) and nine culicine species. In the Canal Zone, *pharoensis* was encountered 22 times of which it was found alone only once (4.6%). It was mostly associated with *multicolor* and *tenebrosus* as well as with eight culicine species. The association of *pharoensis* with *sergentii* and other anophelines in Faiyum and the oases of the western desert is shown under 2.2 above.

In a recent study in Faiyum governorate, El Said et al. (1986) compared the entomological parameters involved in malaria transmission in two villages: Abheet and El Zawyta situated 1 km apart (see under 3.6/.3.7 below). Parallel to anopheline adult populations, larval sampling was extended regularly for a period of over one year in eight productive sites in each village commencing February 1983. The most common anopheline larvae encountered in both villages were those of *pharoensis* and *sergentii*. Larvae of the two species were collected from May to January in both villages, but *sergentii* extended its existence into the winter months. Larvae of two other species: *multicolor* and *tenebrosus* were found only in Abheet. Both had short seasonal prevalence, with *multicolor* encountered during April-June, and *tenebrosus* in May only. Rainfall in Faiyum is practically nil, thus mosquito breeding is associated principally with irrigation water. Larval breeding sites were much more abundant in Abheet than in El Zawyta with most sites occurring close to houses. In Abheet, the most productive sites for all three anopheline species were five low-lying areas where drainage water accumulated. Most of these contained algae, low grasses, sedges and other herbaceous plants around the periphery. Anopheline larvae were most abundant in these sites during May-June and October-December when the water level was high. During July-August these sites dried up considerably and breeding was limited. Abheet village also contained a permanent pond, but larvae were seldom found. El Zawyta village did not have large areas of standing water, with the
exception of one semi-permanent pool 0.5 km south of the villages. Breeding sites in El Zawya consisted primarily of small pools of seepage water from irrigation canals. Secondary sites included irrigated fields of sugar cane and other crops. Rice fields in El Zawya harboured numerous larvae of pharoensis during July-September. Rice was not cultivated in Abheet during the period of study.

3.3 Swarming and mating

No information could be traced concerning the swarming and mating of pharoensis in nature whether in Egypt or elsewhere in its area of distribution in the WHO Eastern Mediterranean Region.

3.4 Dispersal

Kirkpatrick (1925) was the first to point to the long distance flight of pharoensis in Egypt. He indicated that it was found in large numbers in the western desert, far from any water source, having been blown by the constant northerly summer wind.

Much later, Garrett-Jones (1950) reported that on two nights (28 July and 25 August 1942), there were massive mosquito invasions of the camps of the 8th Army in the western desert of Egypt. Inspection of the tents on the following day showed dozens of mosquitoes resting in each tent, the majority being pharoensis. Garrett-Jones considered that the swarms were carried by wind, since there was no large troop movements that could have accounted for the sudden arrival of millions of mosquitoes. A guard on duty on the night of 28 July said that there were no mosquitoes in the early part of the night, but between 0200 and 0300 h, mosquitoes arrived from the north in a cloud which looked like a dust storm by moonlight. The nearest possible breeding place from which these mosquitoes could have originated was a swamp near Alexandria known as Mallahet Maryut situated at 29-45 km from the camps.

Garrett-Jones (1952) discussed the possibility of active long-distance migratory flights by pharoensis in the light of new data reported from Israel by Salternik (1960) and from Gaza by McKenzie Pollock (1960). In 1959, 21 fresh cases of malaria were recorded during July-November at several sites along the Israeli coast, an area from which malaria had been considered eradicated. The cases were scattered over a strip of about 130 km long, from Gaza in the south to Tantura (a settlement situated about 35 km from Haifa) in the north. Routine larviciding operations were carried out in Gaza, and entomological surveys carried out late in 1959 failed to detect any anopheline adults or larvae, while a survey of adjoining territory to the south showed the presence of multicolor larvae only. Thus, Gaza could not be the place of origin of any other mosquito. In the Israeli coastal plain, routine oil larviciding of all permanent breeding places was strictly observed. Following the malaria outbreak, a thorough survey was carried out in the autumn covering all possible breeding places of anophelines. Breeding of pharoensis was detected in 22 localities; the breeding places were almost entirely small, temporary collections of water that were not covered by routine larviciding. This species has only rarely been observed in Israel (and formerly in Palestine) and this was considered the northeastern limit of its range, where it was regarded as a non-vector. The recognized former vectors of malaria in Israel (and Palestine) were sacharovi, claviger, superpictus and sergentii, none of which were found in the 1959 autumn survey in the coastal plain. Thus, there was the inescapable conclusion that pharoensis was the species responsible for transmission of the 21 fresh infections. Susceptibility tests carried out on pharoensis larvae in Ashkelon district in November 1959 showed that the species was susceptible to DDT but resistant to dieldrin. Crops in this district were sprayed in April 1959 with gamma-HCH. However, the presence of pharoensis in April or during the period when HCH would have continued to be a potent selective agent, was considered unlikely. If the species reached the coastal area only in July, it is reasonable to conclude that the invading females were already dieldrin-resistant, and the presence of dieldrin resistance in pharoensis in several localities of the Nile Delta was demonstrated (citing Zahar & Thymakis, 1959). Examination of meteorological records showed that there was a strong wind on the night of 23 July 1959 blowing from the west or northeast on the coast of Israel. It was accompanied by rain, although July is a rainless month. From Gaza, it was reported that a strong wind blew from 15 to 18 September 1959 and that it brought with it a wave of mosquitoes (not identified) which attacked people. During the two unusual weather conditions a full moon occurred on 20 July and on
17 September. If it was certain that the 21 fresh malaria infections in Israel were due to local transmission by pharoensis, it might be surmised that the infected mosquitoes could have arrived from the Nile Delta. This would entail flights of up to 280 km, the distance from Port Said to Tantura. There was no place nearer where in 1959 the conditions of malaria prevalence and vector abundance were such as to offer a more acceptable explanation of the outbreak. In his discussion of these observations, Garrett-Jones felt that this hypothesis may be unfamiliar and therefore may appear far-fetched to malaria epidemiologists, but it would be much more readily accepted by insect ecologists. Some examples of migratory flights in aphids and Aedes mosquitoes were cited and the factors stimulating such flights were discussed. Garrett-Jones further referred to another objection that has been raised concerning the enormous migration that would be necessary to produce the fresh cases of malaria in Israel. He made theoretical calculations assuming that the sporozoite rate of pharoensis at the place of its original flight was 1%. These calculations showed that it would require a population of 10,000 females in the production area to produce each case of malaria in the invasion area, or 10 million females might be sufficient to cause an outbreak of 100 cases of malaria. He believed that insect ecologists would agree that this figure of 10 million females is only a very small population of any insect enjoying a rich breeding ground to which it is fully adapted.

3.5 Local spatial and seasonal distribution

Recent surveys carried out during 1978-1979 confirmed that pharoensis is widely distributed in all governorates of the Delta and the Nile Valley in Upper Egypt including Aswan (El Said & Kenawy, 1983 a & b). It is also present in Faiyum governorate and extends its existence to the oases of the western desert (see 3.2 above) where sergentii acts as a main vector of malaria. In this connection, Halawani & Shawarby (1957) explained that the varying ecological conditions in Egypt influenced the longevity of pharoensis. In the oases where the average relative humidity during summer months (measured over 25 years) is only 30% as compared with 75% in Lower Egypt, the longevity of pharoensis in the oases seems to be short. In the east, it is present in the Suez Canal Zone (Port Said and Ismailia governorates), but has not been recorded in surveys in the Red Sea governorate (Gad & Salit, 1972, and Gad et al., 1987).

In Sinai, initially Kirkpatrick (1925) recorded pharoensis from Bir Fuwara (east of Ismailia) and from Ain Musa (near Suez). Salem (1938) only caught adults of this species from tents on the sea shores at El-Arish, during July-August. In his survey of August 1951, Abdel-Malek (1956) did not encounter pharoensis in northeastern Sinai. Gad et al. (1964) collected large numbers of pharoensis from a few houses and tents at El-Tal El-Ahmar and Gilbana, situated at 10 and 20 km east of Qantara respectively. No breeding places were found in this area, and Qantara East was free of mosquito breeding. The authors suggested that it is highly probable that these mosquitoes were carried by wind from places on the western side of the Suez Canal. On two consecutive days pharoensis adults were abundant, but on the third day none was seen, confirming the absence of breeding in the locality. Probably the range of dispersal of pharoensis is more than 20 km, and it might have reached El-Arish (where it was recorded previously) by the wind or passively by transportation. The authors did not find breeding places of pharoensis in the central and southern parts of Sinai, and the previous record from Ain Musa could not be confirmed.

Margalit & Tahori (1973) in their survey of Sinai did not find any breeding places of pharoensis but captured adults by light trap on the eastern bank of the Suez Canal, probably arriving there by wind from the western side of the canal, confirming the observations of Gad et al. (1964).

On seasonal prevalence, pyrethrum spray collections and observations by outlet window traps conducted by Zahar et al. (1966) during 1959 in Giza governorate in Egypt, showed that pharoensis density was at its lowest level during December-March when the mean daily temperature was about 17.5°C. About the beginning of April, the population started to increase steadily. Breeding conditions became more favourable with the commencement of rice cultivation, and the density peak was reached during July-August. With the drying up of rice fields and the decrease of temperature in October-November, the density decreased and constant took over. The apparent peak of malaria transmission observed in October may have been due to increased longevity of the aging population of pharoensis.
In Faiyum governorate, Soliman, Rifaat & Ibrahim (1967) during 1960-1961 collecting mosquitos resting or biting soldiers in barracks (at 1800-2300 h) found that pharoensis density reached a maximum during August and September when the number of females caught/man-hour was 150 and 130 respectively. The density fell to 3-8/man-hour during January-April. Thus, cold conditions were unfavourable for pharoensis and the data of adult catches were in line with those of larval densities (see 3.2 above).

Recently, El Said et al. (1983) studying the seasonal prevalence of larval breeding of some anophelines in three governorates in the Nile Delta, the Canal Zone and Faiyum governorate during 1978-1979 confirmed that pharoensis breeds throughout the year, with a peak during August when the water temperature was 30-38°C. In contrast, coustani larvae, though present throughout the year, its peak density was reached in winter when the temperature was 17-23°C. It was also confirmed that pharoensis bred in rice fields, but disappeared when rice plantation was terminated, and its place was taken by coustani. In other breeding places, pharoensis continued to be present in winter but in a very low density.

In a more recent study in Faiyum governorate, El Said et al. (1986) determined the seasonal distribution of pharoensis and sergenti from spray capture, man- and animal-bait capture (see under 3.6/3.7 below). In this governorate, it was confirmed that both species act as main vectors of malaria (see under 3.11 below).

In an early study by light trap in the Nile Delta, some information was provided on the seasonal prevalence of pharoensis (see 3.8 below).

In Israel, Saliternik (1974) pointed out that pharoensis had rarely been found in the past and was not considered of any importance in malaria transmission, but in 1959 it appeared breeding in abundance following a period of strong winds, with an outbreak of malaria along the southern coastal plain as well as in Gaza (see under 3.4 above). At present, pharoensis has almost disappeared as only three positive breeding places were detected in 1964, and one in 1965, but none in 1971-1972. In recent surveys reported on by Pener & Kitron (1985b) in northern Israel, pharoensis larvae were encountered only once breeding in a single locality during the period 1974-1983.

3.6 Resting behaviour and 3.7 Biting behaviour

From observations carried out by Zahar et al. (1966) in a study area in Giza governorate in Egypt during 1959, the resting and biting behaviour of pharoensis was studied. Partial pyrethrum spray collections1 in houses yielded low numbers. Analysis of data showed that 67% of the capture stations were negative, 20% had 1-2 pharoensis females, 7% had 3-5 females and only 4% had 6-10 females/room. This indicated that pharoensis is very selective in choosing day-time indoor-resting shelters, with marked preference for animal shelters. Farms containing small numbers of houses were more productive than villages with large numbers of houses: 171 rooms and sheds surveyed in farms gave an index of 1.8/room, while 426 rooms surveyed in villages gave an index of 0.9/room. Collections obtained by spray capture from houses showed a higher proportion of fed than gravid, giving an indication of the exophilic tendency of pharoensis, at least in the later part of the gonotrophic cycle. Confirmation was obtained by window trap observations and searches in natural shelters. Morning and evening collections by outlet-window traps were carried out during July-August 1959, i.e., during the seasonal abundance of pharoensis. In initial observations, relatively higher density was recorded in morning collections: the number of pharoensis females collected from three bedrooms in the morning was 1193, while the same traps yielded 720 in the evening. Since morning collections reflected the exophilic behaviour of the species, it was decided to continue morning trap observations only. From 3-month observations, it was clear that part of pharoensis populations leaves the house in Sella2 stages 2, 3 and 4, while the rest

1. Partial pyrethrum spray capture was made by a cloth sheet 80 x 80 cm supported by two sticks. The sheet was spread and moved around by one collector while another sprayed 0.2% pyrethrin solution in kerosene. For collection from the underside of beds and other furniture, the sheet was spread on the floor. The index derived from this method is roughly about 25-30% of the total room density as determined by the standardized spray sheet method in which the whole floor of the room is covered with sheets.

2. See the description of the blood digestion stages and ovary development of Sella (1920)
remain indoors. The greatest exodus occurred when the females reached Sella stage 6, implying that the endophilic portion of the population leaves the house before reaching the full gravid stage, Sella 7. In two of the three rooms (rooms 1 & 2), a consistently endophilic pattern was observed, whereas in the third room a larger exodus of bloodfed females was invariably recorded. Samples collected by hand capture gave a more endophilic pattern from room 1 where the fed (stages 2, 3 and 4) to gravid ratio was approximately 0.85:1. In room 3 the ratio was about 1.73:1. Searches for pharoensis in natural shelters were not productive during May-June 1959. Farid in 1942 (unpublished observations) found pharoensis resting on rice plants, and this was confirmed by searches in July 1959 in rice fields having plants 50 cm and higher. A cubical tent measuring 14.3 x 14.3 cm and 135 cm high, with its roof and door made of nylon netting and its walls of canvas, was used for sampling pharoensis from rice fields on a standardized basis. The pharoensis density in rice plantations gradually decreased with the drying-up of the fields towards the end of September when cownstani predominated. In another area (Qalubyia governorate), searches were made in natural shelters early in the season (April-June 1960), when pharoensis was only scantily found resting during day-time on various plants, such as clover or young rice, but the density progressively increased in July-August when most of the outside resting was concentrated in rice fields.

Temporary outdoor resting at night was observed on the outside surfaces of walls and doors, as well as on vegetation in the vicinity of houses in the study area of Giza governorate. Wide night searches on vegetation in a radius of about 100 m from houses showed that the plants most preferred were cotton and okra. Fifteen-minute collections every hour from these plants were conducted for three nights. A total of 305 pharoensis females were collected of which 105 were unfed, 111 in Sella stage 2, 45 in Sella stages 3 and 4, and the remaining in Sella stages 5-7. The first appearance of freshly fed females was observed about one hour after sunset, coinciding with the peak of biting outdoors. There was a progressive increase in the proportion of unfed and blooded, as the night advanced. This population completely disappeared with sunrise, and no day-time resting was observed on these plants. These findings suggest that such resting is only a temporary stance, until a further move is made to the appropriate day-time resting sites indoors or outdoors. The phenomenon of pharoensis temporarily resting on cotton plants may help to explain the resistance of this species to DDT and dieldrin that was recorded in unsprayed areas. Cotton plants were treated with organochlorine insecticides in summer, coinciding with the season of pharoensis prevalence. The temporary resting would expose mosquitoes to the insecticide, creating selection pressure on the population. It is probable that the breeding places were also contaminated, producing heavy selection pressure on the larval population.

Observations of man-bait capture indoors and outdoors during July-August 1959 showed that:

(a) pharoensis is an early biter. Outdoor biting started 20 minutes after sunset and quickly reached peak intensity so that 20-40% of the total bites/man/night occurred in the first three hours. Indoors, not more than 3% of the total bites was recorded in the first three hours after sunset, but biting increased gradually until, towards midnight, its incidence indoors and outdoors was almost equal. Before they retire, most of the inhabitants stay outdoors, thus becoming exposed to the early biting peak, then become exposed to the peak indoors about midnight. This apparent adaptation of the feeding habit of the mosquito to the habits of the people must have an important influence on the actual man-biting rate as defined by Garrett-Jones (1964a).

(b) there was a tendency towards renewed attacks outdoors on man and animals in the last hour before biting activities ceased, half-an-hour before sunrise.

(c) the estimated biting rate on a man stationed outdoors varied from 556 in July and 388/man/night in August. The biting rate on an animal (camel) was 2500 and 688/night in July and August respectively.

A similar pattern of biting activities of pharoensis indoors was observed by Soliman, Rifaat & Ibrahim (1967) in Fayyum governorate during August-September 1961. Biting started shortly after sunset and continued throughout the night and during the early morning; the peak of biting was around 2300-2400 h, after which period the activity declined as the morning approached.
Recently, observations were conducted by El Said, Sobhi & Gad (1982) on the biting behaviour of pharoensis in Kafr El Sheikh governorate and the Canal Zone. The results, in general, agree with those obtained by Zahar et al. (1966) in Giza governorate, except for some differences in the Canal Zone. In Kafr El Sheikh, observations carried out in two villages from June to October confirmed that pharoensis is an early biter as it started biting 30 min after sunset. The maximum biting rate from all-night man-bait capture was recorded in June (31 bites/man/hour) when the records of meteorological conditions were (mean values): temperature 22.7°C, relative humidity (RH) 97.8%, and wind speed 31.7 m/s/min. Subsequently, the biting rate decreased until it reached a minimum in October (1 bite/man/hour) when the conditions were as follows: temperature 19.4°C and RH 94.5%. The biting rate was much higher outdoors than indoors. Some observations were made with man-baited nets in comparison with animal-baited nets during June-November. Of a total of 483 pharoensis collected, 15.7% were from man-baited nets and 84.3% from animal-baited nets, indicating the zoophilic tendency of this species. In this comparison, the surface area of man and animal available for biting should be taken into account. In the Canal Zone, pharoensis also started biting immediately after sunset at a high rate - 10.1 bites outdoors and 22.4 bites/man/hour indoors. Thereafter, biting steadily decreased reaching 4.5 bites outdoors at 2100 h, and 5.3 bites/man/hour indoors at 2200 h. Subsequently the biting rate increased to 8.4 at 0200 h outdoors and 11.8 bites/man/hour at 0300 h indoors. The biting rates as illustrated graphically by the authors are quite different from those given in the text and the tabulated data which are shown here. In particular, the graph shows a higher biting rate (about 18) outdoors than indoors (about 9) in the first hour after sunset.

El Said et al. (1986) noted that serological surveys for malaria carried out in Egypt showed that malaria was endemic in Falyun and that parasitological/serological surveys carried out during 1979 in two adjacent villages (1 km apart) in this governorate: Abheet and El Zawyaa gave contrasting results. The parasite rates were 3.3% and 0.8% and the sero-positivity rates were 42% and 21% in the two villages respectively, with both P. vivax and P. falciparum being present. To further check this malaria situation, 20% of the 3000 inhabitants of the two villages were randomly selected and their blood examined monthly during 1983 (citing Hassan et al. - unpublished data). From Abheet a total of 72 cases were detected (22 P. vivax and 50 P. falciparum); while in El Zawyaa only 2 cases were recorded (1 P. vivax and 1 P. falciparum). Therefore, detailed entomological studies were simultaneously conducted by El Said et al. (loc.cit.) to compare the anopheline population dynamics in the two villages and to identify the factors causing the observed differences in malaria prevalence. During these studies oil larviciding continued to be applied by health authorities. Several entomological techniques were utilized simultaneously for one year starting from February 1983, with observations conducted twice monthly. The results of larval survey have been shown under 3.2 above. All-night man-bait captures were conducted outdoors and indoors, collecting attacking mosquitoes for 30 min each hour throughout the night. Four donkey-baited traps were operated in four sectors in the two villages; collection of mosquitoes from these were made every two hours throughout the night. Mosquitoes resting in day-time in houses and animal sheds were collected by pyrethrum spray capture using the index sheet method in which the sheet measured 1 m². As shown above, the sheet supported by two sticks was moved around the room and placed under furniture by one operator while another sprayed a solution of 0.2% pyrethrum in kerosene. This method is commonly used in Egypt, and samples only a proportion of mosquitoes resting in a room, in contrast to the pyrethrum spray capture method described in the WHO Manual (1975) in which the floor is covered by cloth sheets. In each village, six fixed sampling areas were selected at random, and in each, 12 houses and 2-5 animal sheds were sampled at each visit. Sampling of outdoor-resting mosquito populations was done by a battery powered aspirator (described by Nasci, 1981). A series of 5-min collections was made 1-2 hours before sunset and again in the morning. Sampling was conducted within a radius of 400 m around houses covering vegetation surrounding houses, along irrigation canals, and in irrigated fields. Laboratory processing of mosquitoes collected from man- and animal-bait-capture included identification of the species, examination for insemination status, determination of the parous rate using the method of the ovarian tracheoles (Detinova, 1962). Parous females were further examined to determine the number of follicular dilatations (see under 3.10 below), and their salivary glands were examined to determine the sporozoite rate (see under 3.11 below). Longitudinal sampling by different techniques provided information on anopheline fauna of the two villages, seasonal prevalence, biting behaviour including the biting cycle, and the resting behaviour of species encountered as shown in the following:
- Anopheline fauna: Both pharoensis and sergentii were abundantly present in Abheet, while pharoensis was the most predominant species with sergentii scantily present in El Zawyā. Other species encountered were multicolor and tenebrosus, both of which were found in small numbers in the two villages.

- Seasonal distribution: Monthly indices of spray capture, man-bait capture and animal-baited traps were presented graphically to illustrate the seasonal trends of the predominant species, pharoensis and sergentii in Abheet and pharoensis in El Zawyā as shown in Fig. 4. The biting rates of pharoensis exhibited bimodal distribution in Abheet with two peaks reaching 4 and 7.2 bites/man/night in June and November respectively. In the same village, sergentii appeared in fairly low man-biting densities from May to December, with the exception of a peak of 2.7 bites/man/night in November. In El Zawyā, pharoensis exhibited a different seasonal man-biting trend, with peak biting rates of 2.7 and 3.2 in June and August respectively. No biting activities were observed in this village after October. Donkey-baited traps showed similar seasonal trend in Abheet with two peaks of pharoensis appearing in June and October respectively. In the same village, sergentii in donkey-baited traps also exhibited two peaks, one in July and the other in October, unlike man-bait capture in which this species exhibited one peak in November as shown above.

Fig. 4. Seasonal distribution of the predominant Anopheles species determined by man-bait capture, animal baited trap and pyrethrum in Abheet and El Zawyā villages, Faiyum governorate, Egypt, March-April 1983.

1. Reproduced by permission of Dr Sherif El Said and the Journal of the American Mosquito Control Association from the paper of El Said et al. (1986).
- Biting behaviour: Limited numbers of anophelines were collected by man-bait capture during the whole period of observations. The mean biting rates [indoors + outdoors] as calculated from the authors' data (mean of 84 man nights in Abheet, and 80 man nights in El Zawyia) were: \(0.81\) bites/man/night for pharoensis and \(0.33\) for sergentii in Abheet, versus \(0.475\) for pharoensis but zero for sergentii in El Zawyia. Indoor and outdoor biting rates were similar, with the exception of sergentii in Abheet, the indoor component of which was \(0.23\) bites/bait/night. With donkey-baited traps, the calculated biting rates (mean 54 trap nights in Abheet, and 56 trap nights in El Zawyia) were: \(2.7\) bites/bait/night for pharoensis and \(3.4\) for sergentii in Abheet, versus \(1.86\) bites/bait/night for pharoensis and \(0.02\) for sergentii at El Zawyia. No calculation was made for the biting rates of multicolor and tenebrosus, as they were found in small numbers in both villages. The relationship between the man and animal biting rates were presented in terms of ratios (animal:human) as follows: pharoensis \(1.8:1\), sergentii \(5.1:1\), multicolor \(4.7:1\), and tenebrosus \(2.4:1\).

Information on the biting cycle was derived from data recorded in both Abheet and El Zawyia from donkey-baited traps during April–October 1983, grouped into 2-hour periods of observations throughout the night. The peak of biting activities of pharoensis (37% of a total of 247 collected) and sergentii (32% of a total of 186 collected) was observed during the early part of the night, 2000–2200 h, while the lowest biting activities occurred during 0400–0600 h. Man-bait capture gave different results as \(60\%\) of 104 pharoensis and \(79\%\) of 28 sergentii were collected during the first three hours after sunset.

- Resting behaviour: During the whole period of observations, pyrethrum spray collections in houses and animal sheds recorded three species: pharoensis, sergentii and multicolor, with higher densities in AbHEET. In this village, sergentii was the predominant species constituting over 80% and 90% of the indoor-resting anophelines collected from houses and animal sheds respectively, while in El Zawyia only seven sergentii were recorded. While pharoensis was present at low density in Abheet, it was the predominant indoor-resting species in El Zawyia. An. multicolor was collected in small numbers in both villages (total 29 specimens) during April–August, with only one specimen in October. Outdoor-resting searches were performed in over 200 collections by the mechanical aspirator for 5-min each. These yielded 66 pharoensis females and only 1 multicolor female. Most of the specimens were collected from wet sites in irrigated fields, and in vegetation along irrigation canals. Classification of the blood digestion stages was made on samples collected from indoor- and outdoor-resting shelters. Of 59 females of sergentii collected from houses, \(29\%\) were half-gravid and gravid, indicating its endophilic tendency. [The proportion of fed females not shown]. Although sergentii was the most common species resting indoors, it was not found in outdoor-resting sites. In contrast, pharoensis was the least endophilic as only \(6\%\) of 34 females collected resting indoors were gravid, while half of 22 females collected from outdoor-resting sites were half-gravid or fully gravid.

The significance of the differences found between the two villages in relation to the malaria situation is shown under 3.11 below.

3.8 Sampling of mosquitoes in flight

Only two studies could be traced in the use of light traps for sampling of mosquitoes in Egypt. The first was by Hurlbut & Weltz (1956) who observed seasonal and geographical distribution and feeding habits of common mosquitoes, in conjunction with a study of the epidemiology of West Nile virus infection in the Nile Delta. Most of the collections were made in Barada, Sindbis and Quaranfil villages about 30 km north of Cairo. New Jersey light traps were operated from sunset to sunrise, usually four nights/week. The power was supplied by 6-volt, 300 amp-hour storage batteries. Each trap was equipped with a 15 watt clear glass bulb, and a fan which rotated at a speed of 2200 rpm. During the period April 1953–March 1954, the total number of female mosquitoes collected in 608 trap-nights was 16,362, of which pharoensis constituted 99.4%, and the remaining were culicine species. Culex antennatus, Culex univittatus and pharoensis were the most abundant species during July–October. Eggs of Cx. antennatus and larval and pupae of Cx. univittatus and pharoensis were collected in small numbers early in February. This agreed
in general with the seasonal trend depicted by monthly light trap catches which were nil in February for the three species. During September-October 1954, a portable stable trap (of Bates, 1944) was operated at Barada for 26 nights from sunset to sunrise, with a man acting as bait. A light trap was operated simultaneously in the same vicinity at a distance sufficient to prevent interference. *An. pharoensis* and the four culicine species were collected by both traps, with *Cx. antennatus* predominating. Precipitin tests run on 94 bloodmeals of *pharoensis* [from both traps] showed that 97% were positive for man. The percentage of *pharoensis* with blood in stomachs in the man-baited trap was 77%.

The other study was carried out in Abu Rawash, an agricultural village at 15 km northwest of Cairo in Giza governorate by Zimmerman et al. (1988) to determine the host-feeding patterns of mosquitoes in rural areas. The village is situated at the desert edge with three sides facing the Nile Valley farming area. Six solid state army miniature traps (SSAM trap), one at each site, were baited with dry ice suspended in covered 3.8 l cans with punctured bottoms. These were placed directly above the light trap. Traps were placed at nearly equal distances from family living units and associated animal structures and areas. All hosts were equally accessible. The traps were operated from March 1983 to February 1984. Very large numbers of mosquitoes were collected representing five culicine species; and *An. tenebrosus* as the single anopheline species encountered. Collections from walls and vegetation around buildings by a mechanical aspirator yielded four culicine species and *tenebrosus*. No explanation was given for the possible reasons for the absence of *pharoensis* in this area.

3.9 Host feeding patterns

During the studies of Zahar et al. (1966), precipitin tests were made on samples of bloodmeal smears of *pharoensis* collected from different shelters during August 1959 and with the following results:

<table>
<thead>
<tr>
<th>Site of collection</th>
<th>Smears tested</th>
<th>Human % positive</th>
<th>Animal % positive</th>
<th>Mixed: man &amp; bovid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrooms</td>
<td>144</td>
<td>81.3</td>
<td>18.0</td>
<td>0.7</td>
</tr>
<tr>
<td>Animal shelters</td>
<td>140</td>
<td>8.6</td>
<td>90.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Outdoor shelters (plants including rice, cotton, okra etc.)</td>
<td>299</td>
<td>19.4</td>
<td>79.6</td>
<td>0.7</td>
</tr>
</tbody>
</table>

These results together with those of bait capture, show that *pharoensis* is indiscriminate in its biting habits, as it will bite man and animals according to which is more readily available. Considering the smears taken from all resting shelters, the human blood index (HBI) of *pharoensis* in the study area of Giza governorate before spraying was about 32.1% calculated on the basis of the weighted mean, but the method of unweighted mean (Garrett-Jones, 1964b) gave a value of 48.7%. The numerical ratio of man to domestic animals in the area was about 1:7 which was hitherto representative of average conditions in the Delta region. In view of the high density of *pharoensis* in the cattle sheds, and the large proportion of females feeding outdoors, it is probable that the true HBI is less than 32% in August. It may well increase, however, in the autumn when *pharoensis* becomes more endophilic as rice plantations approach harvesting.

In the lists of records of precipitin tests, 1971-1978 consolidated by Garrett-Jones, Boreham & Pant (1980), no data were shown for *pharoensis* except from Ethiopia in the Afrotropical Region, 1971.

As mentioned earlier, a series of studies on host-feeding patterns of mosquito populations has been carried out in different areas of Egypt (see 2.9 above for *sergentii* and *multicolor* in Siwa and Gara oases). In Faiyum governorate, Beier et al. (1987) sampled mosquitoes for precipitin testing from the two study villages: Abheet and El Zawyia in Sinnuris district. The two villages contained about 650 houses with 2500 inhabitants. In both villages, about 75% of the households contained one or more large domestic animals, and half of the houses contained one or more rooms in which animals were kept at night, as commonly observed in Faiyum villages also. Many dogs were observed in both villages, but were not kept in houses and were not counted. Bloodfed mosquitoes were
collected in both villages from houses and animal sheds as well as from outdoor-resting shelters twice monthly from April to December 1983. Sampling from indoor shelters was made by the index sheet method (described under 3.6/3.7 by El Said et al., 1986).

Collection of outdoor resting mosquitoes was done by a battery-powered aspirator (also see above). Bloodfed females were identified and placed in 1.5 ml tubes (up to 50/tube) and frozen at -70°C within two days of collection. As shown under 2.9 above, the method of identification of bloodmeals followed that of Tempelis & Lofy (1963) and details of screening procedures were described. Identification of bloodmeals covered six culicines and three anopheline species; the latter were: pharoensis, sergentii and multicolor. Only the results of anophelines are summarized here. Forage ratios were calculated for the common outdoor species to provide a standard index of host selection. This ratio was calculated for each host category as the percentage of positive bloodmeals divided by the percentage of available hosts. Ratios of more than 1 indicate preference, and ratios less than 1 indicate avoidance, and ratios approaching 1 indicate little preference or avoidance following the method described by Hess et al. (1968). While the three anopheline species were found in houses and animal sheds, only pharoensis was collected outdoors. All bloodmeals gave a positive reaction and thus were identifiable. The proportion of bloodmeals of samples drawn from houses that gave positive reaction for man were: 52% of 31 pharoensis, and 34% of 64 sergentii tested, but there were only two specimens of multicolor, of which one was positive for man. None of 11 bloodmeals of pharoensis and 7 of sergentii collected from animal sheds was positive for man, but 8% of 239 smears of sergentii from animal sheds were positive for man. The results of samples from animal sheds indicate that 86-100% of the three species had fed on large domestic mammals (cow, buffalo, sheep/goat, and horse/donkey). None of the bloodmeals gave positive reaction for dog, cat or rodent, and only 4% of sergentii bloodmeals gave positive for birds. From the outdoor-resting population of pharoensis, 17.9% of 39 bloodmeals gave a positive reaction for man, and this was close to the proportion recorded previously by Zahar et al. (1966) in Giza governorate (see above). The forage ratio was calculated for pharoensis and three culicine species collected resting outdoors. The percentage of hosts in both villages were: 69.3% human, 11.8% bovine, 7.3% ovine, and 11.4% equine. The forage ratio for pharoensis was much below 1 for man, 0.28; 0.94 for bovine; 2.44 for equine; and the highest 5.56 for ovine, indicating the zoophilic tendency of this species. In their discussion, the authors pointed out that the common mosquito species collected resting in houses showed a tendency to feed on man. However, the number of bloodmeals from large domestic mammals suggests that mosquitoes move from room to room within houses in search of hosts, and animals were kept inside most of the houses sampled. It has been shown above that engorged females from animal sheds had fed chiefly on large mammals, with the exception of 29% of Cx. pipiens and 8% of sergentii bloodmeals which contained human blood. If each biotope is considered separately, the proportion of man-fed pharoensis from outdoor sites was 0.179 in contrast to 0.516 from houses. No man-fed pharoensis was obtained from animal sheds. The proportion of man-fed sergentii was 0.344 from houses and 0.084 from animal sheds, but this species could not be collected during 21 h collections by the mechanical aspirator. If all tested smears are considered, the HBI [weighted mean] for pharoensis would be 0.28 and for sergentii 0.14. Despite their zoophilic tendencies, both species are vectors of malaria in Faiyum governorate. Regarding multicolor, the sample size was too small to be considered as mentioned above. The authors underlined the importance of the HBI in quantitative epidemiology, and rightly indicated that this index is sometimes poorly estimated because the inadequacy of sample size and bias in sampling procedures. Finally, the authors remarked that despite the fact that larval densities were high throughout the sampling period in Abheet, relatively few bloodfed females were collected. Further investigation on resting behaviour was suggested as this would facilitate sampling of mosquitoes for host selection studies of malaria vectors in this area.

In Aswan governorate in Egypt, studies on host feeding patterns of 11 culicine and three anopheline species were carried out by Kenawy et al. (1987). The Anopheles species were: pharoensis, multicolor and tenebrosus. Results summarized here are for these three species only. Indoor-resting mosquitoes were sampled by pyrethrum spray capture using the same technique of the index sheet described above. From January 1983 to May 1984, 10 houses were sampled twice monthly in 31 localities in four districts including 21 localities in Aswan itself. Outdoor-resting mosquitoes were sampled using the same type of battery-powered aspirator used in the above study in a series of 520 collections (5 min each). Both indoor and outdoor collections provided information on mosquito species composition in the study area, but specimens selected for bloodmeal identification were
sampled from April 1983 to January 1984. Preservation of bloodfed mosquitoes was as described above, but the specimens were air-dried for several days before being placed in the vials, and most were held dry for one or two months before freezing at -70°C and final processing. Bloodmeal identification followed the same method referred to above. All bloodfed females from the outdoor sites were tested, but since numerous C. pipiens and pharoensis were collected from houses, only specimens collected from March to August 1983 were used for testing. Specimens of the two species were randomly selected by taking 10 females from each vial until about 200 individuals of each species were tested. All bloodfed females of other species from indoor sites were tested. In samples from houses, pharoensis accounted for 2.5% of the total specimens of all species collected (19 641), multicolor 0.7% and tenebrosus 0.1%. In samples from the outdoor sites, pharoensis constituted 4.9% of the total specimens of all species collected (8 640), multicolor less than 0.1% and tenebrosus 0.3%; the sample size of the last species tested from the indoor-and outdoor-resting sites was too small to be considered relevant. The host-feeding pattern of pharoensis and multicolor differed between indoor and outdoor sites. While pharoensis had fed predominantly on man in houses, 62.6% of 198 positive bloodmeals, multicolor showed only 10% man-positive bloodmeals of 70 tested from indoors. Other hosts included large domestic mammals (bovines, ovines and equines). Avian feeds were detected in bloodmeals of the two species. Outdoors, pharoensis predominantly fed on man, 50% of 44 bloodmeals tested. No bloodfed multicolor was collected from outdoor sites. In their discussion, the authors underlined the importance of studying mosquito host-feeding patterns in Aswan, since this area remains receptive to endemic disease occurring in the Sudan, pointing in particular to the spread of malaria through the invasion of An. gambiae s.l. from Sudan during 1942 and 1950, and the spread of Rift valley fever during 1977-1978, probably through transportation of infected animals from the Sudan via Aswan. Malaria is frequently diagnosed in Aswan among travellers from the Sudan, but autochthonous cases are sometimes detected. The area is free from An. gambiae s.l. through the continuous surveillance by the Egyptian Ministry of Health [in collaboration with MOH, Sudan] and control measures are directed against local anopheline species. Of the three species recorded in Aswan, pharoensis appears to be important as a possible malaria vector. Its HBI as shown by the present study was 0.63 for the indoor- and 0.9 for the outdoor-resting sites, the latter index is much higher than that recorded from the outdoor collection in Faiyum governorate (0.18) as shown above. An. multicolor was found only in houses and its HBI (0.1) was much lower than that of pharoensis. Both multicolor and tenebrosus were much less abundant than pharoensis; their vectorial potential appears to be minimal.

3.10 Longevity

In their studies in Egypt, Zahar et al. (1966) determined the physiological age of pharoensis populations in two areas: the field training area (F.T.A.) in Giza governorate, and Marg locality in Qaliubya governorate. The former area was put under DDT spraying after collecting pre-operational data during a brief period in 1960. The latter area was kept unsprayed for comparison. Based on determination of the parous rate by Detinova's and Polovodova's techniques in samples drawn from the populations of pharoensis in the two areas, the following theoretical parameters were calculated:

\[ p = \text{The probability of survival of a female mosquito through one day (\text{\% of daily survival}) estimated by the method of Davidson (1955):} \]

\[ p^n = \text{The probability of survival through the duration of the sporogonic cycle with n denoting the time in days needed for the completion of the cycle (Macdonald, 1957). This parameter was estimated for P. vivax (the predominant infection in the study area), according to the mean temperature at the time, from the tables of Oganov-Rayevski (reprinted in Detinova, 1962, p. 128.).} \]

\[ \frac{1}{-\log_e p} = \text{The expectation of life in days (Macdonald, 1957).} \]

The data of the parous rate and the calculated parameters from the sprayed and unsprayed areas during 1960-1961 are shown in Table 17. It should be noted that while DDT spraying continued to be applied in 1962, the unsprayed area had a very small population
of pharoensis due to unexpected restriction of rice cultivation. Hence, the numbers of
pharoensis dissected from the unsprayed area in 1962 were too small (11 specimens during
the whole season) to be of value for determining the parous rate under natural
conditions. Therefore, the results of the sprayed area in 1962 (not listed in Table 17)
had to be compared with those obtained from the same area in 1960 when favourable response
do DDT spraying was observed. [see Subsection (ii),1 below].

Table 17. Parous rate of pharoensis determined from window trap samples and
calculated parameters for the sprayed area (F.T.A.) and the unsprayed area

<table>
<thead>
<tr>
<th>Area</th>
<th>1960 (spray on 28 June)</th>
<th>1961 (spray on 6 June)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 weeks-pre-</td>
<td>1-8 weeks post-</td>
</tr>
<tr>
<td></td>
<td>spraying (June)</td>
<td>spraying (Jul-Aug)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean tempera-</td>
<td>25.5</td>
<td>27.2</td>
</tr>
<tr>
<td>ture °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Window trap mortality (%)*</td>
<td>-</td>
<td>81.5</td>
</tr>
<tr>
<td>Proportion parous %</td>
<td>F.T.A.</td>
<td>25.7</td>
</tr>
<tr>
<td>(No. dissected)</td>
<td>Marg</td>
<td>(374)</td>
</tr>
<tr>
<td>Value of p</td>
<td>F.T.A.</td>
<td>0.507</td>
</tr>
<tr>
<td>Marg</td>
<td>0.395</td>
<td>0.444</td>
</tr>
<tr>
<td>Value of p²</td>
<td>F.T.A.</td>
<td>0.0016</td>
</tr>
<tr>
<td>Marg</td>
<td>0.000092</td>
<td>0.0015</td>
</tr>
<tr>
<td>1 -logeP</td>
<td>F.T.A.</td>
<td>1.47</td>
</tr>
<tr>
<td>Marg</td>
<td>1.08</td>
<td>1.23</td>
</tr>
</tbody>
</table>

* Immediate and after 24 h holding period.

It is clear from the above data that in June the population of pharoensis was young
at the beginning of the season, and this explains the low probability of malaria
transmission at that time, as indicated by parasitological evidence. The longevity of
pharoensis populations increased from July to September with a parallel increase in
malaria transmission recorded. From July onwards the relative humidity steadily increased
promoting longer survival and the appearance of larger numbers of potentially dangerous
females. But even during the season favourable to malaria transmission, the life
expectation of pharoensis was low. After September, a rapid decline in vector output
occurred, leading to a temporary imbalance in the proportions of parous and nulliparous
mosquitos. For this reason, no assessment is founded on the parous proportions recorded
beyond September. Age-grading of pharoensis populations using Polovodova's technique,
applied on window trap samples from the unsprayed area, showed that out of 1980 specimens
dissected 66.7% were nulliparous, 18.6% had one dilatation, 0.15% had two dilatations,
0.05% (one specimen) had three dilatations and 0.05% (one specimen) had four dilatations.
The remainder appeared with follicular sacs, rendering their age indeterminate.

The paucity of aged individuals shows that although pharoensis appears in high
density with exaggerated biting rates during the favourable season, females of an
epidemiologically dangerous age are still scarce in the population. This may explain the
low sporozoite rate (0.33%) recorded by Barber & Rice (1937) during an epidemic period
(see 1.11 below). From all these observations, it can be concluded that the seasonal
increase in parity is closely correlated with the increase of relative humidity. The
intensity of malaria transmission effected by pharoensis may vary from place to place and
from year to year depending on the relative humidity and the presence of reservoirs of
infective cases. Rice cultivation is a very important factor influencing the density of
pharoensis, both by the extension of the breeding areas and by enhancing the humidity conditions to a level favouring adult survival.

Similarly, low parous rates were recorded in pharoensis in an unsprayed area in Kafr El Sheikh governorate with extensive rice cultivation in the northern part of the Nile Delta, where Shawarby et al. (1967 a & b) conducted insecticide field trials during 1965. The parous rates determined by these authors by dissecting samples from man-bait capture were: 8.8% in the first half of July, 33.3% in the first half of August, 48.1% in the latter half of September.

Observations on the duration of the gonotrophic cycle in pharoensis were carried out during base-line studies in Giza governorate in 1959 by Zahar et al. (1966). During July-August, limited entry of mosquitoes was allowed into rooms at the time of early evening biting peaks. The rooms were sealed thereafter and mosquitoes exiting in window traps were collected periodically on the following days until exodus ceased. All mosquitoes collected were classified according to Sellars stages. It appeared that the majority of the females could reach Sella stages 5 and 6 in about 24 hours from biting. The latest exodus of gravid females (Sella stages 6 and 7) took 41-56 hours. Likewise in the course of susceptibility testing, it was observed that most of the females of pharoensis captured in Sella stages 2 and 3 in the morning reached stages 4 and 5 in the evening and stage 6 by the next morning. These might have fed any time during the night before capture and then 12 more hours would be needed to reach Sella stage 7. Thus, it is reasonable to estimate the duration of the gonotrophic cycle in pharoensis at 48 hours on the assumption that the hosts and the oviposition sites are found without delay, i.e., the time needed for the first and third phases of the gonotrophic cycle (see phases under 1.10 above) is negligible. The mean temperature during the summer months when these observations were made was around 26.4°C.

Age-grading of pharoensis, sergentii and other anophelines existing in two villages in Faiyum governorate was carried out in the course of studies conducted by El Said et al. (1986) applying the method of the ovarian tracheoles and Polovodova's technique during April-December 1983 as mentioned above. All samples dissected were drawn from man-bait capture and donkey-bait traps. The parous rates of pharoensis were: 42.3% (279 dissected) in Abheet, and 33.8% (139 dissected) in El Zawy. Aged individuals were absent; the parous portion in Abheet consisted of 17.9% 1-parous, 2.5% 2-parous, and 21.9% with follicular sacs; and in El Zawy there were 20.1% parous, 0.7% 2-parous and 13.0% with follicular sacs. For sergentii, the data showed that in Abheet the parous rate was 48.7% (234 dissected), and only a single nulliparous female was available in El Zawy. For multicolor, only in Abheet where an adequate sample was available the parous rate was 25% (48 dissected) of which 14.6% were 1-parous and 10.4% with follicular sacs. The duration of the gonotrophic cycle was estimated from laboratory observations which gave a period of four days at temperatures above 22°C (citing Beier unpublished data). Based on this estimate, the value of p was calculated for the period April-December as 0.806 and 0.762 for pharoensis in Abheet and El Zawy respectively, and 0.835 for sergentii in Abheet. Estimates of p from samples collected in November, the peak period of biting activity were: 0.912 for pharoensis and 0.897 for sergentii based on a 6-day gonotrophic cycle estimated for temperatures below 20°C.

3.11 Natural infection

In the past Barber & Rice (1937) recorded an average of 0.33% sporozoite rates in pharoensis (1513 dissected) collected from tents of a hospital encampment at Qaliub, in the southern part of the Nile Delta. The tents were known to harbour carriers of gametocytes of P. falciparum. They remarked that no sporozoite-positive pharoensis were found in their surveys in Egypt except in this encampment, and it was surprising to find a very low sporozoite rate in view of the fact that a large proportion of the specimens in this locality showed a very high oocyst rate. During a malaria outbreak in Gabal El Asfar locality also in the southern part of the Delta, Madwar (1936) recorded in July 1936 a sporozoite rate of 1.4% (138 dissected) in pharoensis.

Subsequently, no sporozoite-positive specimens of pharoensis have been reported in Egypt until El Said et al. (1986) recorded a sporozoite rate of 0.36% (279 dissected) in pharoensis collected by man- and animal-bait capture from Abheet, Faiyum governorate. At the same time, a sporozoite rate of 0.85% (234 dissected) was recorded in sergentii collected from the same village but no sporozoite-positive multicolor was detected.
(48 dissected). As the main objective of this study was to identify the entomological factors that can explain why Abheet had a higher human parasite rate (72 malaria cases) than El Zawya (2 cases), even though the two villages are 1 km apart (see under 3.6/3.7 above), the authors resorted to the calculation of the entomological inoculation rate (EIR) (Macdonald, 1957). This rate is simply calculated by multiplying the man-biting rate x the sporozoite rate. The man-biting rate of pharoensis and sargentii combined was about 308 bites/man/night in Abheet versus 128 bites/man/night in El Zawya for the period of seasonal activity (April-December). Based on the combined sporozoite rate of 0.585 (3/513) for the two vectors in Abheet, the EIR was estimated as 1.80 infective bites/man/season, but no estimate could be made for El Zawya since gland dissection of 139 females of pharoensis gave negative results. In the two villages, multicolor and tenebrosus occurred at such low densities that they could not account for significant malaria transmission. Moreover, the two species are not considered vectors of malaria in Egypt. Thus, the presence of the recognized vectors: pharoensis and sargentii served to maintain a higher rate of malaria transmission in Abheet than in El Zawya, where pharoensis dominated. A further entomological factor that contributed to low malaria transmission came from studies on host-feeding patterns carried out concurrently in the same two villages. (Beier et al. 1987 see under 3.9 above). Whereas the zoophilic tendencies of pharoensis and sargentii were demonstrated, the HBI's for the two vectors respectively were 0.28 and 0.14. Observations by man-bait capture and by donkey-baited traps further confirmed the zoophilic tendencies in both species. El Said et al. (loc.cit.) suggested that factors responsible for maintenance of hypendemic malaria in Fayyum would deserve further consideration if malaria control is to be effective. As shown above, occurrence of both pharoensis and sargentii in Abheet served to maintain malaria transmission at a higher rate than in El Zawya. The extensive breeding sites in Abheet were obviously responsible for higher mosquito densities in this village. Improving drainage of waters associated with irrigation was suggested as the best long-term solution for interrupting malaria transmission.

3.12 Vector resistance to insecticides

The reports of the WHO Expert Committee on Insecticide Resistance (WHO, 1980 - TRS. No. 655, and WHO, 1986 - TRS. No. 737) show that pharoensis from Egypt has been reported resistant to the following insecticides: DDT, dieldrin/HCH, malathion, fenitrothion, fenthion, chlorpyrifos, bromophos, and carbamates. From Israel, pharoensis has been reported resistant only to dieldrin/HCH.

No new reports of susceptibility tests carried out on pharoensis in the present geographical area have been received by WHO during 1984-1986.

Originally, pharoensis in Egypt was susceptible to DDT before 1959 (Zahar, 1960). It was later found to be resistant to DDT and dieldrin even in unsprayed areas. This double resistance was closely related to the extensive use of organochlorine insecticides to control a voracious attack on cotton plantations by the cotton leaf worm, Prodenia litura (Zahar & Thymakis, 1962 and Zahar et al., 1965). Probably, the appearance of OP and carbamate resistance in pharoensis in recent years can also be related to the use of these compounds in agriculture. No biochemical studies have so far been undertaken to investigate the mechanisms of resistance in pharoensis.

4. Secondary and suspected vectors

The available information on the bionomics of most of the secondary or suspected vectors in the present geographical area is not sufficiently detailed to warrant summarizing it under the standard subject headings of vector profiles adopted for major vectors. Thus, a simple review of the available knowledge is made as follows:

4.1 An. hyrcanus

In the USSR, Artemiev (1980) pointed out that irrespective of whether different forms of hyrcanus may eventually be proven good species, they are treated as a single species, An. hyrcanus Pallas, following the recommendations of Gutsevich (1976)1. This species is widely distributed in the USSR south of 50° N. It occurs in Moldavia, southern Ukraine, northern Caucasus, Trans-Caucasus, Central Asia, and around Lake Zaisen

1. See VOL. I (VBC/88.5-MAP/88.2), under 1.2, pp. 39-40.
in the Far East. It is considered a secondary malaria vector in the southern region of the USSR. It can be easily infected with *P. vivax*, less so with *P. malariae* and least with *P. falciparum*. Although it generally acts as a secondary vector in the presence of a major vector, it may play a large role in the transmission of *P. vivax* malaria in certain areas.

The optimum temperature for larval breeding is 25–30°C, similar to that of larvae of the *An. maculipennis* complex, but with the lower limit being 12°C and the upper limit 35°C. In the north, *hyrcanus* breeds in waters heated by the sun, but in the south it prefers shaded sites. Its preferred types of breeding places are: boggy sites supplied by surface water, flood plain puddles, river bends, and in particular rice fields. Nearly all these waters have abundant aquatic vegetation.

In cold regions, its larval development is slow due to the slow heating of the water, hence the adults do not appear in large numbers until July. In Central Asia, *hyrcanus* adults attain high densities in late May and early June, but the density declines in August and the species even disappears in the hottest areas, followed by an increase in September–October. Females of *hyrcanus* hibernate in natural shelters. When the winter is warm, they may feed repeatedly on blood, but this rarely happens even in Central Asia. In the southern part of Central Asia diapausing (pre-hibernating) females appear about the end of September and reach a high density in October. By mid–October, man-biting activity and gonad activity come to an end. In cooler regions, diapause starts somewhat earlier.

Adults of *hyrcanus* prefer to rest outside human habitation. Their natural resting sites are: grasses, bushes, banks of irrigation canals, and crevices in fences constructed of mud. They may change their resting sites depending on the outside temperature, but remain strictly exophilic. They feed on man in the open. There are reports indicating that *hyrcanus* feeds on small animals, but in Central Asia it feeds on man on a large scale in particular those situated near boggy sites or rice fields. DDT resistance was reported on *hyrcanus* in Central Asia, but no reports on possible DDT resistance in this species in other regions of the USSR are available.

In Romania, Cristescu et al. (1975) studied the biology of *hyrcanus* in the Danube Delta region during 1970-1973. Nearly the same biological features as those found in the USSR were recorded. It breeds in shallow waters with abundant vegetation. The first generation appears in May and the density reaches a maximum in July and early August, followed by a gradual decline until it enters hibernation in October. It is an exophilic, eurygamous, exophagic or endophagic species according to circumstances. It is clearly zoophilic as indicated from precipitin tests on bloodmeals of females collected from thatched fences between houses and animal shelters, so that the *hyrcanus* females could feed on either man or animals. The proportion of bloodmeals that gave positive reaction for man was 4.6%. It is considered unimportant as a potential vector in Romania. Confirmation was obtained in the present study from determination of its physiological age during July–September 1972 and during the same period in 1973, using Polovodova's technique. The proportion of females with a maximum number of three dilatations was only 0.32% (934 dissected), i.e., these females were at an age when they start to become potentially dangerous. This supports the assumption that *hyrcanus* cannot have any role in malaria transmission in the Danube Delta region, but it remains one of the most annoying mosquitoes in the Delta. As it exhibited low susceptibility to organochlorine insecticides, the use of *B. thuringiensis* H-14 and analogues of juvenile hormones or by draining shallow swamps were the measures recommended for its control.

In Turkey, Postiglione, Tabanlı & Ramsdale (1973) showed that *hyrcanus* is abundant in the coastal plains and extends its distribution to the Anatolian plateau. It was found breeding in coastal and inland marshes with dense emergent vegetation, rice fields, drainage and road-side ditches with or without vegetation. It was found in association with *sacharovi*, *superpictus* and *algeriensis*. Although no specific studies have been made in Turkey on the resting behaviour of *hyrcanus*, it is known to be predominantly exophilic; the degree of exophily differs between places. Indoor-resting populations are rarely observed in the southern and western coastal regions, but are commonly found in the plateau province of Corum where there is extensive rice cultivation. In this area, *hyrcanus* may be found in human dwellings and in stables. Little is known on the host-seeking pattern of *hyrcanus* in the Mediterranean zone, where it is generally regarded as a wild mosquito having little contact with man. Some observations were carried out in
Ugurlu village, Mugla province of southeastern Turkey. Of 238 hyrcanus females collected simultaneously by man- and cow-baited net traps, 98 were obtained from the cow-baited trap. At the same time, man-bait capture conducted in the same village inside and outside houses, where numerous cattle and other domestic animals are available, as commonly observed in Turkish villages did not yield any hyrcanus. However, when the same human baits were stationed in the open at a distance of 250-300 m from the village, they were quickly attacked by numerous hyrcanus. This showed that man being away from the protection of domestic herds, can readily become a target host for hyrcanus. Postiglione, Tabanli & Ransdale (loc.cit.) further pointed out that in view of its extra-domestic habits, hyrcanus has never been regarded as an important malaria vector in the Mediterranean region and very few investigations (none in Turkey) have been carried out on its vectorial efficiency. In this connection, reference was made to Horsfall (1955) who cited a single record of a sporozoite-positive specimen of hyrcanus from Italy [1/113 dissected]. Both hyrcanus and sacharovi are particularly abundant in the fertile plain of Çukurova which occupies much of the provinces of Adana and Iğdır on the Mediterranean coast. In this plain, hundreds of thousands of seasonal migrant labourers work and sleep in cotton fields, where there are few animals. Thus, an unusually close contact exists between man and both species. Although sacharovi is the more dangerous of the two, the possible involvement of hyrcanus in malaria epidemics in this area cannot be ignored.

In Israel, Barkai & Galiternnik (1968) during their survey in 1963-1965 found hyrcanus breeding in abundance in fish ponds, seepagbs, leakages, springs and irrigation channels. The breeding places were usually stagnant and semi-stagnant waters covered with vertical vegetation. Larvae were found from March to November with a slight increase in summer. Most of the breeding was in Upper Galilee. An. hyrcanus was not considered a malaria vector in Israel (citing Kligler, 1930).

In Lebanon, Gramiccia (1953) pointed out that although sacharovi and superpictus existed in areas of high malaria endemicity as in Bouqaia, Oronte valley towards the Syrian frontiers, these two recognized vectors were associated with hyrcanus which readily bites man. It is a wild mosquito, and it was difficult to find sufficient samples from natural shelters for dissection in order to reach a definite conclusion on its role in malaria transmission. Thus, it should be treated as a suspected vector.

In Syria, Abdel-Malek (1958) encountered hyrcanus along the Orontes valley from Homs to Aleppo. The most northerly breeding place was at Jisr-el-Chagour in Aleppo, where its larvae were found in association with those of sacharovi in a shallow swamp with emergent and floating vegetation at two villages in Ghab area. The most southerly record came from a village on Homs lake, where its larvae were associated with sacharovi and superpictus in a swamp at the edge of the lake with very abundant grasses and reeds as well as patches of floating algae. Adults of hyrcanus were frequently encountered in small numbers in houses, together with sacharovi. Females of hyrcanus attacked man and domestic animals voraciously near swamps during the night until daybreak. Occasional outdoor-biting was recorded in daytime during sunny hours. The author did not give any information on the possible role of hyrcanus in malaria transmission in its area of distribution in northern Syria.

The reports of the WHO Expert Committee on Insecticide Resistance (WHO, 1980-TRS. No. 655 and WHO, 1986-TRS. No. 737.) showed that hyrcanus is resistant to DDT and dieldrin/HCH in Turkey and Afghanistan, and to DDT in the USSR. A wide spectrum of cross-resistance has been reported to the following insecticides: fenitrothion, fenothion, jodphenfos, chlorphoxim, phoxim and carbamates in Turkey, but resistance to carbamates has only been reported from the USSR.

No reports have been communicated to WHO during 1984-1988 on field cases of insecticide resistance in this species from the Mediterranean Basin.

4.2 An. claviger s.l.

In the USSR, Artemiev (1980) showed that An. claviger has a wide distribution in the western part of the country, western Siberia up to Tomsk, the Caucasus and Central Asia. The northern part of its range passes just below the southern range of messeae. In the south, claviger is usually found in the mountains; the southern boundaries of its distribution is determined by an annual mean temperature of about 20° C.
The usual breeding places of *claviger* are springs and wells. The species thrives in cool waters: the optimum temperature range is 14-16°C, the lower temperature threshold is 7-8°C and the upper is 21°C. According to various authors, the larval stage takes 18-20 days in Turkmennia and 32-33 days in Moscow at the optimal temperatures. The preferred larval habitats are shaded sites, and the larvae are indifferent to the presence of vegetation. The larvae can tolerate waters polluted by decaying vegetation, but are sensitive to pollution by nitrogen. Larvae overwinters in the 3rd or 4th instars. In the south, the development proceeds without diapause. In the plains of southern Central Asia, adults of *claviger* appear only in the spring and fall. As the temperature drops in the autumn, *claviger* probably migrates from the mountains to the plains and remains there to overwinter and give rise to adults in the spring. These die in the summer or migrate back to the mountains.

Adults of *claviger* are active at temperatures ranging from 10 to 26°C, with the highest activity being at 13-19°C and 51-95% RH. Normally, they do not fly far away from the breeding habitat. They fly into houses for feeding, but show particular preference for stables as they are attracted to the smell of animals. They are, therefore, more attracted to cattle than man. The adults are exophilic, and leave the indoor shelter after feeding to complete their gonotrophic cycle in outdoor-resting natural shelters such as vegetation, damp banks of canals and other damp sites. As temperatures in such places are low, blood digestion is prolonged, and the gonotrophic cycle lasts about 5-6 days. Swarming and mating of *claviger* occur in the open.

Because of the ecological characteristic of *claviger*, its role in malaria transmission in the USSR was considered slight. It was only on rare occasions that this species was able to transmit malaria when its breeding places were located near human settlements. Malaria outbreaks occurred in the surroundings of Baku Tyen-Shan foothills and on the Black Sea coast of the Caucasus where *claviger* was the principal vector. In the USSR, an autogenous and a nonautogenous form of *claviger* have been observed. In the south, Anopheles habibi, which was misidentified by entomologists as *claviger* is very likely to be present. No resistance to DDT or any other insecticide has been reported in *claviger* in the USSR.

In Turkey, Postiglione, Tabanli & Ramsdale (1972) presented a detailed study of the distribution and ecology of *claviger* in the country. Urban situations suitable for breeding of this mosquito do not exist in Turkey, and even in villages water supplies do not rely on wells and cisterns. Consequently, *claviger* in Turkey is confined to rustic, extra-domestic situations, where domestic animals are abundant. Reference was made to Coluzzi (1962) who classified the An. claviger group into two independent species: *claviger* s.s. and *petragnani*. To ascertain the identity of the Turkish populations of *claviger* s.l., material of preserved specimens existing at the Malaria Institute in Adana that originated from various areas of the country, as well as larvae collected from breeding places in western, southern and eastern parts of Turkey, were examined. This showed that all Turkish populations sampled belong to *claviger* s.s., thus providing additional evidence on the restricted range of *petragnani* which has so far not been detected in the Eastern Mediterranean Basin, where *claviger* s.s. exists in Balkan, Turkey and the Middle East [See Fig. 11 in SECTION II in document VBC/90.1-MAL/90.1]. In all areas of Turkey, *claviger* could be occasionally found resting indoors, as it is largely exophilic. It feeds, to a certain extent, in villages, but it generally attacks man or domestic animals wherever they are available in the open. The contact with man is usually accidental and occasional. Although widely distributed in Turkey it prevails in the warmer parts of the country, but its density is markedly reduced in summer. An exceptional situation occurs at Savur in southeastern Turkey, where many springs in extensive poplar plantations provide ideal and permanent breeding places for *claviger*. During the summer months, large numbers of people work and sleep in poplar plantations, where they become heavily attacked by *claviger* amongst other species. It is quite possible that in such situations, *claviger* has some role in malaria transmission in formerly malarious areas, although numerous gland dissection failed to find a sporozoite-positive specimen, thus it could not be considered a good vector. Since the environmental conditions in Turkey differ markedly from those found in urban areas in the Middle East, but closely resemble those found in the Balkan countries, it was concluded that *claviger* in Turkey is of minor importance in malaria transmission, and has little influence on the receptivity of areas where transmission has been interrupted.

1. See VOL. I, pp. 34-36, in Document VBC/88.5 - MAP/88.2.
In their study of the anophelines of the Maghreb, North Africa, Guy & Holstein (1963) discussed the role of claviger in malaria transmission in the light of the results of determination of the physiological age made on samples collected from the mountainous regions of Algeria and Morocco. Epidemiological evidence supports the view that claviger takes over from labranchiae and transmits malaria in late autumn (see under 2.10 above).

Gramiccia (1956) presented a detailed account of the ecological features of claviger and the associated epidemiological situation in countries of the Middle East, where this species is widely distributed. Within a small area of its distribution, claviger exhibits a variety of ecological features as follows:

(a) In towns, it breeds in underground water reservoirs, and it is chiefly a domestic species as its adults rest in houses.

(b) In rural areas, it breeds in water reservoirs, and it is chiefly extra-domestic as its adults rest mostly outdoors, especially after feeding, or on the walls of wells, but in the autumn it becomes domestic, and engorged females are frequently found indoors.

(c) As a natural water breeder, it is mostly a wild species unimportant in malaria transmission.

The host-feeding pattern of claviger is probably dependent on the availability of hosts near its breeding sites, but it attacks man readily in the open and in daylight with varying intensity depending chiefly on the season and prevailing temperature. In case of situation (c) above, it passes the winter chiefly in the larval stage, but a few overwintering adults have been found in outdoor-resting shelters. In cases of (a) and (b), however, it continues its larval development and adult activity, including mating and feeding, throughout the winter as the microclimate inside the wells permits.

Gramiccia (loc.cit.) further showed that claviger had been reported in the past to be a vector of malaria in certain areas (Palestine, Cyprus, Lebanon, Mesopotamia, southern Italy, Baku--Azerbaijan) and had been considered a non-vector in many other malarious areas (Central Italy, Greece, Balkans, Iran and others). It was rarely found alone as a vector species, usually being associated with the recognized main vectors, chiefly: sacherovi, superpictus and sergentii. Sporozoite-positive specimens of claviger were recorded in Cyprus (citing Stratman-Thomas, Barker & Carter, 1936), Taranto, Italy (citing Hargreaves, 1923), and Mesopotamia (citing Christophers & Short, 1921). [This last record from Mesopotamia which appears also in Boyd (1949) could not be confirmed - see Muir & Keilany (1972) below]. Gramiccia (loc.cit.) further added that there was full epidemiological evidence that claviger was a vector in Palestine; Jerusalem, for example, was among claviger-infested Palestinian towns. An. claviger was the only anopheline species present, and its abundance and the hyperendemicity of malaria hitherto recorded during 1912, left no doubt as to its role as a vector. House wells provided suitable breeding for claviger, which was probably able to produce hyperendemic malaria because it had little chance to feed on anything else but man. Larvicidal treatment of wells, water piping and the destruction of unused wells in subsequent years brought about complete control of malaria. On the other hand, claviger was not a vector in areas where it was breeding in natural waters and where many alternative hosts were available. In Lebanon, Gramiccia strongly suspected claviger as a vector in some hilly villages where several wells were present. On the other hand, claviger together with superpictus were found in almost every coastal, hilly and mountainous area, wherever there were wells up to 1200-1500 m altitude, and the distribution of claviger had no direct relation to the malaria endemicity in the area. This was an example of "unstable anophelism without malaria". In a limited number of localities on the dry limestone hills of Lebanon, both spleen and parasite indices were recorded. Although superpictus females migrated at one time or another to nearly all these villages, [see 2.4 above], their numbers and activity were too small to account for the malaria infection there. An. claviger was the only abundant indigenous species in these localities. Thus, it was presumed, but not definitely proven, that claviger was the principal or the only malaria vector there. The spleen and parasite indices, however, were so low and so uneven in the dry hill villages that it was considered possible that claviger would be unable to maintain malaria transmission indefinitely in a sedentary population without visits from time to time of gametocyte carriers from elsewhere. In Dedde village situated on the hills of southeast Tripoli, all cases of parasitaemia were recorded among children who had not left the village during the preceding two years. Dissection of 433 claviger, however, proved negative. After antilarval treatment of cisterns that started in July 1953, the parasite
rate dropped to zero during October-December. Regarding control, Gramiccia indicated that residual house spraying was not found to control claviger, while larviciding did. This, in the light of the probability that claviger can maintain occasional transmission of malaria for some time after the commencement of house spraying, larval control simultaneously with residual spraying programme should be implemented for at least the first two years. The cost of such larval control would be much less than that of extending the residual spraying programme for a prolonged period.

In Israel, Saliternik (1974) recalled the observations of Barraud (1921) in Palestine which showed that claviger was the most abundant domestic mosquito, breeding principally in shaded cold rain water of the courtyard cisterns or inside houses. Under such conditions, claviger became in close contact with man, readily biting him and transmitting malaria. It responded readily to control measures carried out during 1919-1926 (hermetic sealing of cisterns, provision of piped water, larviciding operations etc.). Now, claviger is no longer important in malaria transmission. It is found mainly in the north of Israel and often away from human dwellings. No morphological differences could be found between larvae of claviger collected from cisterns and streams.

In the recent report on anopheline fauna of northern Israel by Pener & Kitron (1985b), larvae of claviger were identified from 106 breeding places in the course of surveys made during 1974-1983. This species has been collected in increasing numbers in recent years with its relative frequency ranging from 7 to 30%. It was generally restricted to spring-early summer breeding, and was the most or second most common mosquito from March to July. An. claviger was often found within or near Arab villages where wells and cisterns are present in Safed and Acre regions. It is less common in the Jordan Valley. In the Safed region, constani was always present, but algeriensis which was prevalent until 1980, declined and was possibly replaced by claviger by 1981-1983. In Acre, claviger and superpictus increased as algeriensis declined. An. claviger was found 13 times in the same locations and months in 1982-1983, while algeriensis was found in 1977 (mostly in the upper Galilee and Acre region). In these locations, claviger was absent in 1977, while algeriensis was absent in 1982-1983. Thus, it seems that an actual replacement of algeriensis by claviger, and to a lesser extent by superpictus may have taken place, but the authors cautioned that his cannot be proved in the absence of experimental data.

In Syria, Soliman (1960) reported the results of observations carried out during October 1957-September 1958 on the seasonal distribution of claviger and its susceptibility to insecticides. The observations were conducted at Der El-Asafir village, 10 km south of Damascus, where claviger was found breeding in open marshes around some natural springs. Following Gramiccia (1956), claviger in this area could be considered a natural breeder, hence a wild mosquito unimportant in malaria transmission. The seasonal distribution was studied through weekly larval sampling. The area was under DDT house spraying. The results were summarized as follows:

- As indicated from larval catches particularly younger instars, the density of claviger fluctuated throughout the year, with no particular decline during winter.
- The breeding activity reached a peak in July, and the lowest densities were observed in April, August and September.
- The changes in the seasonal distribution were not related to DDT spraying, as this mosquito was considered exophagic and exophilic.

Larval susceptibility tests showed that claviger was completely susceptible to DDT and HCH. It was concluded that the lack of response to residual house spraying while claviger remains susceptible to the insecticide would suggest that larviciding would be the measure to use for effective control of this species. However, the application of such a measure was not recommended for this area, since it proved to be non-malarious.

Muir & Keilany (1972) cited several authors indicating that claviger has been regarded as a vector of malaria in urban areas and in villages in Syria, Lebanon, Jordan and Palestine, but there were no records of its actual incrimination in these countries through finding sporozoite-positive specimens in nature. Reference was made to Boyd (1949) who listed one record from Mesopotamia of one sporozoite-positive among a small number of claviger dissected by Christophers & Short (1921). Checking the original publication of the two authors, Muir & Keilany (loc.cit.) could not trace such a record,
and thought that it may have been a misquotation. In October 1970, a malaria outbreak occurred in Al-Bellora village on the outskirts of Aleppo, where 58 indigenous cases of *P. vivax* were detected among 113 inhabitants. *An. claviger* was the only anopheline found in the area, and its breeding was found in wells and cisterns in the limestone bedrock. Dissection of 20 females of this species yielded two sporozoite-positive specimens. This was the first confirmed incrimination of *claviger* as a vector of malaria in the area bordering the eastern littoral of the Mediterranean. Oil larviciding in wells and cisterns in the above-mentioned village led to interruption of malaria transmission.

In North Africa, Senevet & Andarelli (1956) gave the distribution of *claviger* in the Mediterranean Basin including Morocco, Algeria and Tunisia. In the last two countries, it does not exist very far from the sea, the farthest point being in valleys about 30 km from the sea. In Morocco, it extends to the Atlas up to 2560 m altitude. It was found to breed in freshwater at shaded sites even those having no vegetation, and small pools formed in mountainous streams, as well as in wells in the dry regions. In Algeria, it was found breeding in winter in waters at temperatures of 11-16°C, and during its full evolution in the autumn at 19°C. It was found practically all year round in Algeria reaching a maximum in winter and spring and a minimum in summer. Some records of natural infections reported from Italy in the past were cited, but none from North Africa.

Guy & Holstein (1968) showed that *claviger* finds favourable conditions in the Moroccan Atlas; it was found breeding in streams descending from this mountain range. It was also found slightly above the 31° N latitude in the pre-Saharan regions. Age-grading of a sample of *claviger* obtained from the mountainous regions in Algeria and Morocco where this species occurs in abundance, showed that only 0.7% of the females could complete five gonotrophic cycles, which theoretically can allow the sporogonic cycle to be completed. This raises a question whether *claviger* has a potential role in malaria transmission during the autumn, but the sample dissected was too small to lead to a valid conclusion - (see more details under 2.10 above).

*An. claviger* has been included among the anopheline vector species that have not been reported to have developed insecticide resistance (WHO, 1980 - TRS. No. 655) and no susceptibility test reports involving this species have been communicated to WHO during 1984-1988.

4.3 *An. hispaniola*

Senevet & Andarelli (1956) indicated that the main area of the distribution of *hispaniola* is the western part of North Africa (Morocco, Algeria and Tunisia) where it extends from the Mediterranean littoral to Tamanrasset right into the Sahara. It also exists in the Canary Islands. In the Moroccan Atlas and Algeria it is commonly found from 0 to 1200 m altitude. Although the Edm. and Et. Sergent brothers found a sporozoite-positive in *hispaniola*, the role of this species in malaria transmission in North Africa could not be established with certainty as it is almost always found in association with the main vector, *labranchiae*. Moreover, *hispaniola* is a zoophilic and exophilic mosquito, although it can under certain conditions enter houses and bite man, but this seems to be episodic. Thus, the role of this species appears to be limited. In Libya, it was recorded from Tripolitania and Cyrenaica in Libya (Macdonald, 1982). It has never been recorded in Egypt except from the high mountain (above 1200m) areas in Sinai (Margalit & Tahori, 1973). In Israel, it was rarely found in the past and was not considered a vector, and it could not be found in surveys made during 1963-1965, (Barkai & Saliternik, 1968).

Guy (1963) referred to the single record of the Sergent brothers (shown above), and pointed out that on another occasion sporozoite-positive specimens were found in *hispaniola* during a circumscribed malaria epidemic that broke out in 1948 in Midlet, Morocco, where it was the only anopheline species present. On the other hand, precipitin tests showed that only 0.7% of *hispaniola* females had fed on man. Epidemiologically, this was a favourable characteristic because *hispaniola* is most widespread in Morocco and in Algeria. Susceptibility tests showed that *hispaniola* was completely susceptible to DDT.

Guy & Holstein (1968), trying to find evidence on the role of *hispaniola* in malaria transmission, age-graded a large sample of this species collected from different areas in Morocco (see under 2.10 above). Under the climatic conditions of the transmission in Morocco, none of the *hispaniola* females could survive to the completion of the sporogonic
cycle. This led to the conclusion that *hispaniola* does not seem to be a natural vector of malaria in Maghreb.

In Algeria, Ramsdale (1972) remarked that *hispaniola* is a wild mosquito, normally having no contact with man; it is not considered as playing an important role in malaria transmission.

In Tunisia, before the malaria eradication campaign, it was thought that *labranchiae* and *hispaniola* were the principal vectors, but later evidence showed that *hispaniola* did not play any important role in malaria transmission as indicated by Wernsdorfer (1973).

No reports have been communicated to WHO indicating the presence of insecticide resistance in *hispaniola*.

4.4 An. *d'thali*

This species has a widespread distribution (see SECTION II, under 2.2.3 in document VBC/90.1-90.2). In the Mediterranean Basin, it was recorded in North Africa (Morocco, Algeria, Tunisia and Libya). It has not been recorded in Egypt except from the Sinai by several authors. In Israel, it was rarely encountered in the past and was not considered a vector; it was not found in surveys made during 1963-1965 (Barkai & Saliternik, 1968). No natural infection has been found in *d'thali* in any country of the Mediterranean Basin.

In Morocco, Guy (1963) indicated that *d'thali* was first recorded in 1959, and it was a suspected vector of malaria, but some salivary gland dissections were negative. It existed in association with *sergentii* but in a more restricted area: Ziz and Draa streams. It appeared late in the season and did not last for a long time. Its anthropophilic index was thought to indicate its probable role in malaria transmission. Precipitin tests made in 1961 at Zagora (at the same place where *sergentii* was tested a month later) showed that 21.2% of 160 females of *d'thali* had fed on man. All that has been said about *sergentii* south of the Atlas applies also to *d'thali* in that it has the same breeding habit and adult resting places in houses as *sergentii*.

Guy & Holstein (1968) pointed out that *d'thali* was recorded in northern Morocco in the Moulouya valley. Because of the oblique position of the Moroccan Atlas, there is a climatic barrier that would oppose the extension of the *d'thali* range of distribution from its traditional habitat in the south of the Atlas to get established in the area of large rivers in the north close to the Mediterranean coast. However, *d'thali* remains a suspected vector playing some role in malaria transmission south of the Atlas.

In Algeria, *d'thali* is more widely distributed in the southern than in the northern oases (see Tables 1a & b, under 2.5 above). Ramsdale (1972) described *d'thali* as a desert mosquito, never incriminated definitely as a malaria vector, even where it is abundant.

4.5 An. *multicolor*

The general distribution of *multicolor* and its status as a suspected vector on epidemiological grounds have been shown in SECTION II, under 2.2.4. (in the same document as above). It is reputed to tolerate high salinity in breeding places, although it can also breed in freshwater (see under 3.2 above).

In Morocco, Guy & Holstein (1968) showed that *multicolor* extends its area of distribution in the southern Atlas to colonize the plains situated between Marrakesh and the Atlantic, and further north to Tangier spreading abundantly in pockets along the Mediterranean coast. It seems that *multicolor* plays a role in malaria transmission in Morocco and in certain oases in southern Algeria, but so far it has not been incriminated except on an epidemiological basis.

In Algeria, Holstein et al. (1970) found that some of the early records of *multicolor* and its association with the malaria epidemiological situation in the Saharan oases appeared to have been based on erroneous identification of a morphologically abnormal form of larvae of *hispaniola*, which resembles *multicolor*. Ramsdale & Zulueta (1983) supported this view, as they observed that *multicolor* is not as widespread as the early records indicate, at least in Hoggar and Tassili. The most recent distribution
records of multicolor in the northern and southern oases of Algeria were presented by these authors as shown in Tables 13a and b respectively. Holstein et al. (loc.cit.) further pointed out that while some early workers associated multicolor alone with endemic-epidemic conditions of malaria in the Sahara, there were others who found that although multicolor was abundantly present, malaria endemicity was very low. Investigations carried out by the authors in Tassili, Hoggar, Timimoun and Biskra in Algeria, led to the conclusion that malaria encountered in its low endemicity with epidemic bouts in these areas was due to sergentii. It is often difficult to provide evidence on the role of a species such as sergentii because it has a very short season corresponding exactly to the season of epidemiological manifestations. This can explain why multicolor which breeds prolifically in brackish water and has a long seasonal prevalence (even its larvae are found in winter) was incriminated as the obvious species present associated with epidemic episodes. Intensive studies undertaken in Biskra revealed the absence of malaria transmission in oases where multicolor stands alone all year round. Thus, it is necessary that investigations should be carried out on malaria transmission occurring in the oases of the Sahara at the time of seasonal prevalence of sergentii, i.e., during September-November.

Ramsdale & Zulueta (1983) pointed to Ouargla oasis in northern Algeria as an example of situations where multicolor has been regarded as a vector on epidemiological evidence. In this oasis, a low level of P. vivax transmission persisted and was studied by many workers for several years, during which multicolor was the only anopheline found. However, evidence for the involvement of multicolor in some other places in Algeria has been less convincing.

In Tunisia, Wernsdorfer (1973) indicated that the distribution range of multicolor covered the southern part of the country and Sfax governorate, as well as part of Kairouan region, but its role in malaria transmission could not be ascertained except on epidemiological grounds. It seems to have contributed to malaria transmission in the foci of Sayada/Smara in 1971 and El Mendria in 1972, where it was found in high densities.

In Libya, Goodwin & Paltrineri (1959), who described the malaria situation before the commencement of the malaria eradication programme in 1960, pointed out that while multicolor had a wide distribution, sergentii existed sporadically. An multicolor has never been definitely proven to be a vector, but in the Fezzan region malaria was found in isolated oases where multicolor was the only anopheline encountered. A very high density was apparently necessary for transmission to occur. It was found breeding in small pools tolerating high salinity; the total chloride contents in the breeding water was 14.4g/l. The tolerance of this species for salinity probably accounted for its wide distribution in the oases where the majority of the water was saline. The species was found in great abundance in the dry season breeding in small saline pools of standing water resulting from surface evaporation. It was found to be anthropophilic and readily rests indoors.

More recent information on multicolor in Libya has been incorporated with that of sergentii under 2.5 above. Additionally, Ramsdale (1989 - in press) indicated that larvae of multicolor in Libya thrive in polluted water collections in urban areas, producing high adult densities which can maintain a significant level of man biting despite the preference of the species for non-human blood.

Some information is available on age-gradings multicolor in Libya. Shalaby (1973) initially applied the technique of the ovarian tracheoles on samples from a laboratory colony to study the structural changes in this tracheal system after the first oviposition. Subsequently, the method was applied on samples of field populations of multicolor collected from three localities in Fezzan province. The results showed that of 83 multicolor females collected from Sebha locality (February-October 1968), 34.9% were parous; of 95 females of the same species collected from El Gedid locality, Libya (January-October 1968), 16.9% were parous; and of 33 collected from Brak (September 1968), 12.1% were parous. Thus, of a total of 211 females of multicolor dissected from the three localities 23.2% were parous. While describing the changes occurring in the ovaries and ovarioles of pharoensis and multicolor drawn from laboratory colonies, Shalaby (1971) gave some details of dissections made by Polovodova's technique on wild-caught females of multicolor collected from Sebha and El Gedid during January-October 1968. Of 138 females, 76.81% were nulliparous, 21.74% 1-parous, and only 1.45% (2 specimens) were 2-parous. The area received two rounds of DDT spraying annually between 1966 and 1969, at 2 g/m² in each round. [The absence of aged individuals probably reflects the impact of DDT spraying, but no dissections were made from an unsprayed area for comparison].
In Egypt, Halawani & Shawarby (1957) pointed out that although Kirkpatrick (1925) considered multicolor to be a vector on epidemiological grounds, and even though Barber & Rice (1937) found no difficulty in infecting multicolor experimentally, this species has never been shown to act as a natural vector of malaria in the country. In fact, Barber & Rice (1937) mentioned that although they could infect multicolor in the laboratory from gametocyte carriers of P. falciparum, it was not found infected in nature, but the number dissected was very small (13 specimens). Similarly, despite the fact that in recent laboratory experiments in Egypt by El Said & Farid (1982) multicolor could be infected from P. vivax patients producing very high sporozoite rates [see VOL. I, document VBC/88.5-MAP/88.2, pp. 153-154], no sporozoite-positive specimens could be found in multicolor during an investigation by El Said et al. (1986) in one of the villages in Faiyum governorate. At the same time, sporozoite-positive females were recorded in pharoensis and sergentii in the same village, but the numbers dissected were much larger than in the case of multicolor (see under 3.11 above).

Larvae of multicolor in Egypt were found to breed in waters having a wide range of salinity up to 21.25 g Cl/l (see 3.2 above) and also a wide range of pH, 6-13. The preferential breeding places were found by Gad et al. (1982) to be: seepage waters - the most favourable, followed by brackish water pools, small water collections, drains and wells, while rice fields gave the poorest yield (0.07% of the total larvae collected). Some information on the resting and biting behaviour of multicolor was given by El Said et al. (1986) from their observations in Faiyum governorate (see 3.6/3.7 above). The zoophilic tendency of multicolor was shown by precipitin tests run on limited samples collected from Siwa and Gara oases as well as Aswan governorate respectively by Kenawy et al. (1986 & 1987) (see 2.9 and 3.9 above). On its spatial and seasonal distribution, multicolor was shown by Halawani & Shawarby (1957) that it was found all over Egypt and was more abundant in the oases. It appeared to be more prevalent during the colder part of the year, from October to April, presumably because its favourite breeding places, the seepage waters, dry up during the warmer months. In the Red Sea western coast, Gad & Salit (1972) found multicolor breeding at Qoseir in small and moderate sized pools exposed to the sun without vegetation. It was also collected from Wadi El-Ambag, 8 km west of Qoseir. This wadi is a depression between mountains, where frequent springs and brackish seepages existed in many scattered sites. In their survey of the Red Sea governorate, Gad et al. (1987) after intensive search, found only eight larvae of multicolor at Marsa Alam and two larvae at Qoseir in April 1982 and July 1983 respectively. The larvae of multicolor were also found breeding in cesspits containing high sewage contents, the water of which was brackish. The associated species was Cx. pipiens [The same conditions was observed by Ramsdale (1989 - in press)]. In Sinai, all authors who surveyed this area recorded multicolor in several localities, the last of whom were Margalit & Tahori (1973) (see under 2.2 above). These authors recorded multicolor breeding in waters with very high salinity at En Umm Achned. No breeding places for this species were encountered on the eastern side of the Suez Canal, but its adults were collected by light traps. It was assumed that these adults were probably carried by wind from breeding places on the western side of the Suez Canal. In this connection, Kirkpatrick (1925) pointed out that multicolor can travel for considerable distances aided by wind, as he found it in the eastern desert about 8 miles (12 km) from the nearest possible breeding place.

In Israel, Saliternik (1974) noted that multicolor has been suspected as an occasional vector on epidemiological grounds in arid foci. Its distribution was mainly limited to brackish water containing up to 3.5% salinity. In hotter and drier years the number of its breeding places rose in consequence. In the recent report of Pener & Kitron (1985b) multicolor was found breeding only in five localities in northern Israel, representing 0.4% of the breeding places inspected. Data were not sufficient to depict its seasonal pattern.

With regard to its reaction to insecticides, the reports of the WHO Expert Committees on Insecticide Resistance (WHO, 1980 - TRS. No. 653 and WHO, 1986 - TRS. No. 737) show that multicolor is resistant to DDT and dieldrin/HCH in Saudi Arabia; to DDT, malathion, fenitrothion, fenothion, chlorpyrifos, and bromophos in Egypt. No new tests have been reported to WHO during 1984-1988 on this species from the Mediterranean Basin or elsewhere.
Subsection (ii): EPIDEMIOLOGY AND CONTROL OF MALARIA

1. Epidemiological studies and control operations

The status of malaria eradication and problems associated with imported malaria in continental Europe have been dealt with in SECTION I under paragraph 1 (document VBC/90.1-MA9/90.1). The present subsection covers principally other countries of the Mediterranean Basin, for which an overview of the malaria situation has also been given in SECTION I under 2.1. The available information on epidemiological studies and malaria control or eradication operations in these countries, as well as information on the most recent malaria situation as communicated to WHO/MA9 by the WHO Regional Offices1 are summarized here. It should be re-emphasized that insecticide field trials whether conducted on a village or a larger scale, which were evaluated only entomologically, i.e., without a corroborating parasitological evidence are omitted from this review with a few exceptions.

In Turkey, following the malaria epidemics that broke out in the mid 1970's, attention has been focused on the underlying factors as a basis for implementing rational remedial measures. Ramsdale & Haas (1978) briefly reviewed the malaria situation in Turkey following the establishment of the malaria eradication programme in 1957 which became operational in 1960, after many years of malaria control. As a result of this programme, the incidence of malaria decreased annually, malarious areas became more restricted, and the transmission of P. falciparum ceased. By 1973, the total number of malaria cases detected was 2438, and there was only a small area in the extreme southeast of Turkey remaining under the attack phase. With the decline of malaria as a major problem, and because of demands of other aspects of public health importance, and as resources were limited, the malaria service became under continuous pressure to reduce expenditure. On the other hand, there were signs indicating deterioration of the epidemiological situation, for resurgence of malaria occurred in various areas of Turkey under the consolidation phase. In 1976, the number of malaria cases detected increased to 37 321. The most serious development occurred in the first eight months of 1977 when outbreaks of 83 383 cases were detected. This necessitated the reinstition of attack operations in the large and economically important region consisting of the Chukurova and adjacent plains. Reorganization of the malaria service in Turkey should be done on the basis of the receptivity and vulnerability to reintroduced malaria, since conditions varied between places. To assist this task, the authors considered the factors interacting in malaria transmission with special reference to Turkey.

Factors related to the parasite: Previously P. falciparum occurred in all countries of the Mediterranean Basin, but its requirements of relatively high temperatures for completing its sporogonic cycle limited its northerly distribution. In contrast, P. vivax which requires lower temperature could extend its distribution to northern Europe. Temperatures below which development of the sporogonic cycle is indefinitely retarded lie between 14.50 C and 160 C for P. vivax, and 160 C and 190 C for P. falciparum (citing Macdonald, 1957; Moshkovsky, 1946; Pampana, 1963). Reference was also made to Macdonald (1957) who considered that in regions with marked winters, the risk of P. vivax transmission remains slight until the mean temperature reaches 210 C. With P. falciparum, the risk of transmission remains slight until temperatures 3-40 C higher (i.e., 24-250 C) are reached. Using data provided by the Turkish Meteorological Service maps were constructed showing the months in which mean temperatures of 240 C and 200 C are attained. These temperatures are 10 C lower than the critical temperatures, in order to allow a margin of safety in the delimitation of high risk areas. In all areas of Turkey, temperatures fall during September-October, but because of the existence of already infective mosquitoes, malaria transmission could continue even though temperatures have fallen below the critical levels for sporogonic development. However, areas having longer and hotter summers will be, in general, more receptive to reintroduced transmission with either P. vivax or P. falciparum. With the exception of the Aras valley near the Soviet and Iranian borders, areas with temperatures suitable for the transmission of P. falciparum are restricted to Marmara, Aegean and Mediterranean littoral, as well as the relatively low-lying regions of southeastern Anatolia which occurs at the extreme north of the great plain of Syria and Iraq. Areas of establishment of P. falciparum in the interior part of the country are very limited, being confined to the large river valleys.

1. This information has been provided through the cooperation of Mr J. Hempel, MAP/EME.
principally that of the Euphrates. Although occasional imported cases of *P. falciparum* were still observed, all indigenous cases of malaria in 1977-1978 were *P. vivax*.

Different authors referred to experiments that indicated that European anophelines are refractory to exotic strains of *P. falciparum*. However, the authors believed that the apparent inability of *P. falciparum* to re-establish itself in Turkey must be largely due to the relatively short season during which conditions are suitable for completion of the sporogonic cycle. On the other hand, transmission of *P. vivax* is possible over a much greater part of Turkey. However, conditions favourable for transmission for more than three months (i.e., where the critical level of temperature is attained before July) occur in a more restricted area. This area includes some of the Black Sea coastal plain and the valleys of some of the larger rivers that penetrate into the plateau, in addition to the areas suitable for *P. falciparum* transmission. In large tracts of northern and eastern Turkey, summer temperatures are never sufficiently high to support *P. vivax* transmission. Also, the summer is so short in areas where the critical temperature of 20°C is not attained until August, that the parasite would have great difficulty in establishing and maintaining itself. The rest of the central plateau, the eastern highlands and the Black Sea coastal areas, where the critical temperature is reached in July, can be regarded as marginal with regard to *P. vivax* transmission, with malaria outbreaks amenable to remedial measures. In fact, many foci of transmission which occurred on the plateau were eliminated without difficulty, despite the presence of vector species in abundance and a high incidence of imported cases in at least one area. In regions with long, hot summers, the temperature rises rapidly early in the year, mean temperature levels of 20°C and 24°C are often reached at the same time. It is in these regions that conditions are most suitable for transmission of *P. vivax* and *P. falciparum* as well. Entomological investigations showed that the risks of malaria transmission before July are slight in the European part of Turkey as well as in other inland villages, and that the peak of the transmission season in these areas would not occur until August or September or even October. It is only in the Aegean and Mediterranean coastal plains where mild winters and long summers prevail that transmission can occur earlier.

- Factors related to mosquito vectors: *An. sacharovi* is the important vector in Turkey. Other species of the *An. maculipennis* complex, *An. superpictus* and *An. hyrcanus* may play a role in malaria transmission in certain situations but none approach *sacharovi* in vectorial importance. The authors summarized the available knowledge on the breeding habitat, spatial and seasonal distribution, and resting and biting behaviour (see above under 1 for *An. maculipennis* complex, 2 for *superpictus*, and 4 for *hyrcanus* in Turkey). The authors further pointed to the factors interacting in malaria transmission such as the size of the parasite reservoir, the duration of the sporogonic cycle, and the density and longevity and the degree of contact with man of the mosquito vector, most of which are difficult to estimate in nature. In order to estimate the risks of malaria transmission by *sacharovi* in Turkey, the authors resorted to theoretical calculations using some estimated entomological parameters. Since residual house spraying has been applied in Turkey, vector density cannot be reliably estimated from daytime capture of mosquitoes resting indoors. Instead, density estimates were based on catches made by man-baited and animal-baited nets operated simultaneously outdoors. To iron out fluctuations in the relative proportions of the total catch in successive collections from these net traps, the unit of measurement adopted was the density per bait per night (i.e., the mean number caught in the two nets). None of the Turkish anopheline vectors are predominantly anthropophilic and all feed outside. From temperature records and *sacharovi* density estimates obtained from Kavakli village in Central Anatolia during 1967, calculations were made to determine the earliest possible date at which *sacharovi* can inflict an infective bite as shown here in Table 18a. (Fig. 5a has also been reproduced to show the location of different areas and population movement in Turkey as shown below).

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2. Table 18 and Fig. 5 have been reproduced by permission of Mr C.D. Ramsdale and the Transactions of the Royal Society of Tropical Medicine and Hygiene from the paper of Ramsdale & Haas (1978). Fig. 5 has been redrawn by Mr Ramsdale to be more clear (personal communication, 1989).
Table 18. Model showing seasonal trend of risk of acquiring An. sacharovi transmitted malaria due to P. vivax in the village of Kavakli (1010 m) in Central Anatolia during 1967, assuming that all mosquitos would become infected at the observed bloodmeal, and a daily mosquito mortality of 10%.

<table>
<thead>
<tr>
<th>Date of observed bloodmeal (Observation period)</th>
<th>Density/night of sacharovi taking possibly infected bloodmeal</th>
<th>Duration of extrinsic cycle in days</th>
<th>Date of earliest possible infective bloodmeal</th>
<th>Infective density</th>
</tr>
</thead>
<tbody>
<tr>
<td>I May 24-26</td>
<td>1.00</td>
<td>35</td>
<td>June 28-30</td>
<td>0.003</td>
</tr>
<tr>
<td>II June 13-16</td>
<td>4.88</td>
<td>26</td>
<td>July 7-10</td>
<td>0.39</td>
</tr>
<tr>
<td>III July 4-6</td>
<td>16.75</td>
<td>25</td>
<td>July 25-27</td>
<td>1.83</td>
</tr>
<tr>
<td>IV July 25-28</td>
<td>550.88</td>
<td>10</td>
<td>Aug 11-14</td>
<td>91.45</td>
</tr>
<tr>
<td>V Aug 14-18</td>
<td>1733.75</td>
<td>24</td>
<td>Sept 3-6</td>
<td>210.30</td>
</tr>
<tr>
<td>VI Sept 5-7</td>
<td>981.00</td>
<td>indefinite</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VII Sept 25-27</td>
<td>46.00</td>
<td>&quot;</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VIII Oct 16-17</td>
<td>0.25</td>
<td>&quot;</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1 Calculated as: density in man baited trap net plus density in animal baited trap net, divided by 2
2 Calculated by the method of Oganov-Rayevsky (Oganov, 1947), cited by Detinova, 1962, assuming a mean temperature during the extrinsic cycle equal to: mean temperature during the observation period plus mean temperature during succeeding observation period, divided by 2
3 Assuming a daily mortality of 10% during the extrinsic cycle, and that all surviving mosquitos would be infective

This table was presented as a model for the type of calculation that can be made for the onset of the transmission season. It was not meant to portray the actual risks of P. vivax transmission, since the area has been free of malaria for at least 20 years. However, the data show that even when the risk of transmission is grossly exaggerated, by assuming absolute anthropophily of the vector, and a parasite reservoir comprising the entire human population, the probability of acquiring an infection in July would be slight, and that the main transmission season could not start until August or reach its peak in September. This represents one month or more after the temperature has risen to the critical level above which transmission of P. vivax could occur. The temperature again fell below the critical level in September, when the size of the biting population had also started to decline. In this part of the plateau, anophelism without malaria has been known for a long time even in the absence of control measures. Nevertheless, transmission can occur up to, and above this altitude, as witnessed in 1972 when an outbreak of P. vivax occurred near Bor in the east, the causes of which are shown below. Because of the very short transmission season, malaria outbreaks at this altitude were easy to control, even when large vector densities existed.

To compare the projections made for Kavakli, calculations were also made using data of temperature and sacharovi biting densities recorded at five villages situated in different parts of Turkey: Mavit, Arill (first catchment area), Kutchuk Karataş (Chukurova), Balluja (Chukurova), and Golyaka. The seasonal density trends of potentially infective (vivax) densities of sacharovi in the five villages were presented graphically. This showed that at Mavit, where sacharovi was abundant in 1968, and at Arill, where lower densities were recorded in 1970, the probability of receiving an infective bite before July was remote, and that the peak of the transmission season would have occurred in September. The critical level of temperature for transmission of P. vivax (20°C) was reached in July in the parts of southeastern Anatolia where these villages are located. In the coastal plain villages of Golyaka, Kutchuk Karataş and Balluja, the critical temperature for P. vivax transmission was reached in May, thus the appearance of
potentially infective vectors began earlier, and by June when the critical temperature for
P. falciparum transmission was attained, the potentially infective mosquitoes were already
plentiful. Instead of continuing to rise to an autumn peak as in central and southeastern
Anatolia, densities of *sacharovi* in all three villages declined, and by August and
September, potentially infective mosquitoes became rare. The considerable reduction in
mosquito densities during the summer resulted from crop spraying, in the absence of which
potentially infective *sacharovi* density would have increased to a late summer or autumn
peak.

- Factors related to the human host:
  
  (a) Aspects of human ecology influencing man-vector contact: In Turkey, cattle
  and other domestic animals are abundant in every village and this substantially reduced
  man-vector contact. During the summer season cattle are stalled outside, between houses,
  making them readily available to mosquitoes. Several examples were given to illustrate the
degree of man-vector contact under varied conditions in Turkey. On the plateau,
inhabitants in villages sleep indoors throughout the year, often on upper stories, the
ground floors being reserved for cattle and storage. Under these conditions, residual
house spraying reduced man-vector contact, as mosquitoes that can succeed in penetrating
the animal barrier and enter sleeping rooms, become irritated or killed by the
insecticidal deposits. In the hotter parts of Turkey, people sleep out of doors during
the summer. Residual house spraying is not as effective in these areas as it is in the
plateau. Both human and animal hosts are found out of doors, and the vector populations
also exhibit marked exophily. Nearly all these villagers sleep under mosquito nets.
Although these nets are sometimes in bad condition or improperly tucked in, they provide a
certain degree of protection against mosquito bites. However, all the human population
spends the evenings out of doors eating, drinking or talking, thus becoming exposed to
mosquito attacks. *An. sacharovi* was able to maintain malaria transmission in villages,
despite the presence of cattle and in the face of deficient spraying coverage. However,
treatment of parasite carriers together with residual house spraying had an immediate
effect on transmission. This was observed during the attack phase operations in
southeastern Anatolia between 1967 and 1970, and occurred equally in areas under HCH,
dieldrin or DDT spraying.

In southeast Anatolia, there is a vast rugged area lying on both banks of the Dicle
(Tigris) river. This area consists of dry rocky plateaux broken by hills and deep ravines
through which streams flow. Where there is sufficient soils, rice fields are established
on both banks, producing enormous numbers of vector populations including *sacharovi* which
is restricted in its distribution. *An. superpictus*, though occurring in many places from
which *sacharovi* is absent, is also restricted to the proximity of the streams. On the dry
plateaux of southeastern Anatolia, wheat and barley are grown. As the mills for grinding
these crops are driven by water power, they are situated near streams and are usually in
rice cultivated areas. Because the distance involved may be considerable, farmers take
their families with them and camp outside the mill, awaiting their turn to grind the
crops. During this period, they come in close contact with *sacharovi* and *superpictus* when
the risk of transmission is at its peak. Close contact with the vectors also occurs in
the hotter regions of Turkey during the autumn when cotton and rice are harvested.

Another area of epidemiological importance is the lower Meritch valley which is a
centre of extensive rice cultivation. The Meritch river forms the border between Turkey
and Greece, but its flood plain lies within Turkey. Although no rice is cultivated in
this part of Greece, both Greek and Turkish villages overlook large areas of rice
cultivation. Cattle and other domestic animals are abundant in all these villages.
People engaged in the maintenance of the irrigation canals and pumps live throughout the
summer in permanent and semi-permanent houses in the valley, but large numbers of
temporary workers camp on the edge of the rice fields during harvest. Most villagers
(men, women and children) return to their houses to sleep, but during the harvest they
reach the fields at dawn and return only at dusk. *An. sacharovi* is much more numerous in
the valley than in villages, and is active at dawn and dusk, as well as in shady places on
the edge of the fields chosen by the inhabitants for a mid-day rest. Entomological
investigations revealed that most, if not all, of the malaria transmission in this area
occurred in the fields. During four years of a malaria outbreak that occurred in the
Meritch valley, only one case was found in the Greek border villages. The only difference
between the two sides of the frontier was that the villagers on the Greek side spent every
night in their villages, while those on the Turkish side worked and often slept in the valley, particularly during the harvest.

During the past 20 years, vast agricultural development occurred in Turkey. In the larger coastal plains, and also in some other areas, marshy or waste land has been drained and reclaimed or improved. In these areas, the ecological conditions have been completely changed with water being available through the construction of dams or exploitation of sub-surface water supplies. Traditional farming has been replaced by cultivation of single cash crops, especially cotton or rice. In the Chukurova plain which represents the largest of these areas, the resident rural population has reached about 0.5 million people [in 1978]. Nevertheless, the demand for agricultural labour cannot be met locally. For this reason, there is an influx of about 750,000 seasonal labourers coming mostly from southeastern Anatolia. These labourers sleep in the open outside villages where no domestic animals exist, thus they come in close contact with *sacharovi* and *hyrcanus* which are abundantly present in the plain.

Although the absence of animals is an important factor contributing to conditions favourable to malaria transmission, malaria actually occurred amongst herdsmen sleeping in the open. As mentioned above, an outbreak occurred in the upland plain of Bor, in Central Anatolia, in 1972. Investigations showed that all cases were among herdsmen and their families who sleep outside villages. Each night, cattle belonging to several families are driven into enclosures distributed throughout this marshy plain. Around these enclosures, family groups sleep in flimsy, temporary, open shelters. Mosquitos, predominantly *sacharovi*, attracted by the animals have to fly through the ring of herdsmen, and feed sufficiently on man to maintain malaria transmission. Another factor that contributed to the development of this outbreak was the movement of members of family groups of herdsmen to the malarious plain of Chukurova, seeking work in cotton fields. This ensured a high rate of importation of cases into the Bor area. Because of the short duration and the relatively cool conditions in the summer season in the upland plain of Bor (1250 m), the outbreak was brought under control and curtailed without difficulty.

(b) Aspects of human ecology influencing the dissemination of the parasite reservoir: As the human host is the principal vehicle for dissemination of the parasite, a detailed knowledge of population movement is important for the planning and organization of the malaria programme. Population movement in Turkey takes many forms. There is a continuous flow of people from the countryside to larger urban centres, principally Istanbul and Ankara. This movement is well documented, but is not of great importance in the spread of malaria. On the other hand, traditional movement by nomads following seasonal grazing, or by semi-nomads taking their flocks to upland pasture areas for the summer, have been the means by which the malaria parasite was carried from the low-lying areas of the coast or southeastern Anatolia to the central plateau and eastern highlands. These movements are less well documented. The authors gave some examples of population movements in relation to the dissemination of the malaria parasite, in the hope that this would form the basis for more detailed studies of this aspect of epidemiology. A map was presented to illustrate the directions of different population movements as shown here in Fig. 5.
Fig. 5. Giving schematic representation of some seasonal population movements in Turkey and showing areas involved.

Key:
- Important irrigation projects
- Seasonal movements of agricultural workers: established
- Developing
- Nomadic movements with flocks
In Van province at a minimum altitude of 1725 m, the summer season is short and grazing in winter is poor because of the extreme cold and heavy snow. Therefore, people starting from August move with their herds down to the valleys to spend the winter on lower ground near the borders of Syria and Iraq, and they return in the spring. They pass through rice growing areas of southeastern Anatolia in September, often camping on the edge of rice fields. Until recently this low lying region was intensely malarious. Many malaria cases detected in the east and southeast lake Van contracted the infection in this region. In the Van lake area, *sacharovi* is absent and climatic conditions are marginally suitable for malaria transmission.

Traditional seasonal population movements occur in all parts of southern and southeastern Turkey. Many families own land on the plain and also in the hills, so that some members remain on the plain to cultivate the land, while others accompany the animals in the hills. During the summer there is much interchange between the people on the plain and those in the upland pastures. This movement ensures the dissemination of the malaria parasite. As mentioned above, families accompanying their herds often spend the summers in tents camping near water, and in such situations *superpictus* was able to maintain malaria transmission in southwestern Turkey in areas where *sacharovi* is absent.

Other types of movement of the population in Turkey include gypsies, itinerant workers engaged in construction, logging and similar projects, and camping tourists. These types have been increasing, bringing closer contact between people and the vectors, thus providing ample chances for wide dispersal of the parasite. However, the most important type of movement of the population is the seasonal migration of agricultural workers to the large irrigation projects. The reasons for the deterioration of the malaria situation in Chukurova and Hatay plains could be traced to the malarious areas of migrant labourers in southeastern Anatolia and particularly Adiyaman zone, which was the site of an important malaria outbreak during 1968-1972. As the movement of these labourers is in two directions, they are now importing malaria parasites from Chukurova and Hatay plains to their places of origin. Consequently, malaria has again become a problem in parts of southeastern Anatolia. In recent years, there has been a tendency amongst immigrants in the Chukurova plain to settle on the outskirts of the towns and cities in sub-standard structures constructed on undrained sites where excavations create ideal vector breeding sites. There is a continuous interchange of the human population between these outskirts. the cotton fields of Chukurova and the areas of origin of the immigrants, and consequently malaria has become a serious urban problem in this area. The irrigation projects of the Chukurova plains are examples of several other projects in the Mediterranean, Aegean and Marmara coastal plains and also in some inland areas, where cotton and rice are being cultivated. Hence, the demand for seasonal labourers is continuously increasing. [More detailed information on the Chukurova project is shown under (ii), 2 below]. Seasonal workers from southeastern Anatolia are already being attracted to the coastal plain of Antalya. This tendency will increase annually, and will soon include other areas of southwestern and western Turkey as shown in Fig. 5, thus facilitating the dissemination of the malaria parasite to new receptive areas. Malaria transmission in Turkey has been a matter of concern to neighbouring countries and also to other more distantly situated countries having close contact with Turkey, because of fear of importation of malaria with increased travel.

To conclude, the authors underlined that the resurgence of malaria in recent years in southern and southeastern Turkey has created a new epidemiological situation in the country. The main aims should be the containment of the increasingly serious problems, and to prevent the spread of malaria transmission to other receptive areas. Only after this is achieved will it be possible to think again of malaria eradication. Widespread vector resistance to organochlorine insecticides (citing Ramsdale, 1975), but this did not create an insurmountable problem to the progress of the malaria eradication programme, although it necessitated the use of more expensive and toxic compounds. On the other hand, incipient resistance to OP and carbamate insecticides in southern Turkey has been a matter of much concern, calling for more urgent tasks to contain the malaria situation before the development of a high degree of resistance to these insecticides that would preclude their future use. This resistance resulted from the application of agricultural pesticides, (citing Ramsdale, 1975), and its further evolution will continue irrespective of antimalaria measures. [In fact, the presence of OP and carbamate resistance in *sacharovi* in Turkey has been clearly demonstrated in recent years by Ramsdale, Herath & Davidson (1980) and Hemingway et al. (1985) - see VOL. I: document VBC/88.5 - MAP/88.2, under 2.6.2, pp. 94-98.]
The authors further pointed out that although the situation of insecticide resistance has been causing much concern, the deterioration in the epidemiological situation in Turkey must be attributed mainly to operational deficiencies arising from administrative and financial constraints. Containment and reduction of malaria outbreaks will involve increased expenditure, but this would also be expected in other countries with endemic malaria. In this connection, it should be remembered that the concept of total coverage spraying has been changed to the principle of selective operations according to malariogenic potential and changing conditions. The main target would be the application of remedial measures with a minimum of delay, and this would go a long way to provide more effective operations at a minimal cost. They reiterated that the reorganization of the malaria service of Turkey was outside the scope of their present paper, but the discussion of the factors influencing malaria transmission would provide the basis for such reformation. As has been shown above, the length of the transmission season is a key factor in the epidemiology of malaria. This is limited by the temperature requirements for the development of the sporogonic cycle, and vector behaviour. In most of Turkey, the risk of contracting malaria is slight, and the curtailment of outbreaks is not difficult. When the transmission season is limited, the re-establishment of malaria transmission from small origins becomes more difficult. Human ecology has been found to be an important factor influencing malaria transmission, involving closer man-vector contact in the hotter parts of Turkey. It has also been shown that the danger of the spread of malaria to new areas depends on population movements. The extent of this movement and of the malaria situation is continuously changing with economic development occurring in different parts of the country. Data on population movement in Turkey are not complete, and the whole subject of human migration awaits profound and continuous study.

The WHO (1978 - Wkly Epidem. Rec.) summarized the malaria situation in Turkey and the factors that contributed to the development of outbreaks as follows:

Malaria almost disappeared in 1968, when only 37 imported P. vivax infections were reported. The malaria incidence, however, started to build up again gradually until alarming epidemic proportions were reached in 1976 and 1977 when 28 849 and 101 742 cases were detected respectively. The provinces affected were: Adana, Içel (Chukurova) and Hatay (Amikova) south of Taurus range on the Eastern Mediterranean coast with a total population of about three million. These areas have been under agricultural expansion during the last two decades, following the construction of dams and large irrigation systems.

The factors that led to this situation include:

- Increased receptivity due to the extension of the irrigation system which favoured the proliferation of breeding places for *sacharovi* created by waste waters in drains, rice fields and marshes.

- Re-establishment of malaria transmission in a few urban centres where rapid and uncontrolled expansion favoured the creation of new breeding places.

- The presence of parasite carriers among 500-700 thousand labourers who move into Chukurova/Amikova every year from southeast Anatolia at the beginning and during the transmission season.

- Indiscriminate use of pesticides, applied by air on cotton fields leading to the evolution of resistance to DDT, dieldrin, fenithion, bromophos, fenitrothion and propoxur.

- Inadequate surveillance coverage during 1971-1975 in the highly receptive and vulnerable areas of Chukurova/Amikova.

Since 1977 every effort has been made to reorganize and strengthen the national antimalaria service. In 1977, and especially in 1978 when the assistance of the international community and of various United Nations Agencies became available, an emergency plan to control the epidemic was implemented. Diversified control measures have been applied in an attempt to curtail transmission and prevent the spread of malaria into nearby receptive areas and neighbouring countries.
Following the reorganization of the antimalaria programme of Turkey in 1977, a large scale control campaign was initiated in 1978. Onori & Grab (1980) carried out a study to determine quantitatively how the malaria epidemic might have evolved if control measures had not been applied. The antimalaria measures implemented in 1978 in the Chukurova and Amikova plains were shown to be as follows:

(a) all malaria cases discovered in 1977 were treated for a second time in early 1978;

(b) malathion house spraying (2 g of technical malathion/m²) was applied twice: the first round during 15–April-15 May, and the second during 15 July-15 August;

(c) larviciding operations in and around urban centres started in March and continued, but with an interruption of 3–4 weeks during the period of higher transmission until October. Fuel oil which was used in March–April was replaced by temephos from June onwards;

(d) the larvivorous fish, Gambusia affinis was widely distributed in all irrigated areas throughout the year;

(e) mass drug distribution was implemented in the most receptive areas from May to October, but always with low population coverage and inadequate supervision;

(f) increased routine surveillance activities were continued throughout the year.

Failures occurred in the course of implementing the various field activities. These were due to the very short time available for the reorganization of the antimalaria services and to serious logistic difficulties. However, the results achieved during 1978 clearly indicated that the epidemic was contained. Onori & Grab (loc.cit.) used a mathematical model similar to that of Muench (1959) to project the epidemiological situation that would have prevailed under natural conditions from 1978 to 1980. The following simplified assumptions were adopted:

(a) The forecast was developed on the basis of the number of blood slides found positive for malaria parasites monthly from January 1976 to December 1978, assuming that the number of positive slides reliably reflected the monthly malaria incidence. It was further assumed that the slide positivity rate was sufficiently low during the off-season, and not excessively high during the transmission season, thus providing an indirect assurance that the slides examined were properly selected and adequate in number.

(b) It was assumed that the seasonal dynamics of vector populations remained unchanged from year to year.

(c) Although the evolution of an epidemic situation is characterized by a high rate of increase in the annual number of cases, it was assumed that this rate decreases slightly with time due to development of immunity in the human population, and probably also because a certain fraction of the population was not actually exposed to the risk of infection.

(d) To facilitate computation, it was further assumed that the population of Chukurova and Amikova plains was constant and equal to 3 million, a figure which was an approximation of actual population estimates for the years 1976–1978.

The technique used consisted essentially of projecting the trend and determining the upper limit of:

- the seasonal minimum monthly number of cases (in January);
- the seasonal maximum monthly number of cases (July/August).

For interested readers, the mathematical expressions used for the projection of the minimum and maximum monthly incidence should be read in the original paper. The observed monthly parasite incidence recorded in 1976–1978, and the projected incidence for
1978-1980 were presented graphically as shown here in Fig. 6\(^1\), and the observed and projected parasite incidence for the period 1976-1980 were tabulated as shown in Table 19\(^1\). As shown in Fig. 6, the impact of the intervention measures applied in 1978 became perceptible in June. The peak shown in May was explained by the occurrence of some early transmission that was not controlled by the first round of malathion spraying. Transmission decreased markedly during the summer months when it should have been at its peak. The benefits from the 1978 intervention were indirectly quantified by estimating the number of malaria cases that would have occurred in Chukurova and Amikova plains if remedial measures had not been implemented. In their discussion, the authors emphasized that the evolution of the epidemic that occurred in this area of southern Turkey in 1976 and 1977 could have been studied and the situation in 1978 could have been projected by the use of the basic reproduction rate of MacDonald (1957), if all the variables involved in the transmission dynamics had been estimated. This could not be done because data on mosquito density in relation to man, its seasonal variation, vector longevity and degree of anthropophily were not available for the period under review. Therefore, resort was made to an adaptation of the catalytic model developed by Muench (1957). To appreciate the potential development of an epidemic, as estimated by this forecasting approach, the observed and projected annual parasite incidences shown in Table 23 should be compared. The observed parasite incidence was more than three times higher in 1977 than in 1976. A further increase of 2.1 times was foreseen for 1978, if intervention measures had not been applied; the projected parasite incidence/1000 population would have then reached 100.9 in 1979 and 115.1 in 1980. When the number of malaria cases actually detected in 1978 (70 468) was compared with that projected in the absence of intervention (226 252), it could be deduced that about 2/3 of the expected cases were prevented in 1978 by the application of the remedial measures. Although the precision of this estimate is not known, the reduction of malaria transmission observed in the Chukurova and Amikova plains is indisputable. Finally the authors underlined that caution should be exercised when attempting to apply this empirical approach to other situations. Accurate and precise forecasting is, however, a pre-requisite for the evaluation of the impact of public health activities, particularly the communicable diseases programmes. Therefore, sound, valid and reliable forecasting methods are needed.

A report of an evaluation meeting held in Istanbul during November 1979\(^2\) recalled that in a previous meeting in Copenhagen in November 1978, the malaria programme in Turkey in 1977 was reviewed and the country was divided into four epidemiological strata according to the level of malarial risk potential. Accordingly, the following strata were defined:

- **Stratum I** covers the provinces of Adana, Iğdır and Hatay. Stratum Ia which had 101 867 cases in 1977 represented the nucleus of the malaria epidemic, and Stratum Ib covered the whole of southeast Anatolia where localized outbreaks also occurred in 1977 (11 131 cases).

- **Stratum II** considered to be at high malaria risk, included the whole western part of Turkey plus the province of Niğde, Nevşehir and Kayseri in the central part of the country.

- **Stratum III** covered mainly the high plateau of the central Anatolia. The malaria risk was considered to be low, but minute foci were recorded in a few localities in 1977.

- **Stratum IV** included the northeastern part of Turkey and the provinces of Zonguldak, Kastamonu and Sinop on the Black Sea Coast. The malaria risk was considered to be very low.

According to the most recent information received from Turkey, these epidemiological strata have been mapped as shown in Fig. 7\(^3\).

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Fig. 6. Monthly incidence of malaria-positive slides observed in 1976-78 and incidence projected for 1978-80, Çukurova and Amikova plains, Turkey.


<table>
<thead>
<tr>
<th>Year</th>
<th>Annual parasite incidence per 1000</th>
<th>Ratio of successive values for annual parasite incidence$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Projected</td>
</tr>
<tr>
<td>1976</td>
<td>11.1</td>
<td>•</td>
</tr>
<tr>
<td>1977</td>
<td>35.9</td>
<td>•</td>
</tr>
<tr>
<td>1978</td>
<td>24.5</td>
<td>75.4</td>
</tr>
<tr>
<td>1979</td>
<td>•</td>
<td>100.9</td>
</tr>
<tr>
<td>1980</td>
<td>•</td>
<td>115.1</td>
</tr>
<tr>
<td></td>
<td>Upper limit</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ In the absence of intervention.
From a report of a meeting held in Ankara during February 1985, the malaria situation in Turkey and future plans were discussed. The report shows that with the collaboration of WHO, a new plan of action was prepared in 1977 and the concept of malaria control was accepted as the new strategy. Following the implementation of various control activities, the number of malaria cases dropped to 29,000 in 1980. However, due to various constraints and problems, there was a gradual increase in the number of cases which reached 66,000 in 1983. With sustained efforts, the number of cases decreased to 55,000 by the end of 1984.

The report also shows that the Turkish Government has set the objective of malaria control as “interruption of malaria transmission in the country by 1989”. As Turkey is one of the countries that expressed the will and determination to adopt and implement the social target of “Health for All by the Year 2000”, the Turkish Government has adopted the PHC principle as the main strategy to reach this target, and has declared that malaria is one of the priority public health problems. This decision has led to the reorganization of PHC structure and services at central and peripheral levels, together with the integration of the Malaria Control Services into the PHC Services. This has created the need for reconsideration and replanning of ongoing malaria control activities. The scope and aims of the meeting were shown as follows:

- "Revision and evaluation of the present malaria situation and antimalaria measures in 1984 in each malaria stratum of the country.

- Evaluation of the actual functioning of the new PHC/MAL integrated approach and future aspects.

- Assessment of the constraints and urgent needs in physical and human resources for reaching the ultimate objective and adjustment of such a plan of action to resources available by selecting priority actions in priority areas of intervention.

- Determination of strategy for 1986 and the needs required to implement it."

The two major items discussed in the meeting were:

Evaluation of 1984 activities and identification of constraints:

(1) Antivectorial measures:

a. Residual house spraying constituted the main antivectorial activities. With the exception of the Adana region, the spraying operations were not performed as planned. In Stratum Ia in particular, pirimiphos-methyl replaced malathion, though costing 2-3 times more, because of the community resistance to malathion spraying, and the additional advantage of airborne toxicity of pirimiphos-methyl. However, the spraying coverage was almost the same. In most places, the application of the correct dosage and designed spraying rounds was not achieved due mainly to the shortage of trained and motivated personnel, inadequate amount of insecticides and transport difficulties. Community resistance to house spraying, in general, contributed to the ineffectiveness and coverage of insecticide application.

b. Some winter fogging and space spraying were carried out on a focal basis.

c. Bacillus thuringiensis H-14 and larvivorous fish (mainly Gambusia affinis) were tried as biological control measures. B.t. proved to be extremely effective provided that repeated applications are made, but this would entail a financial burden including the high cost of the original formulation. Production of B.t. locally will be difficult to achieve. Horizontal vegetation reduced the effectiveness of G. affinis which is bred and widely distributed in Chukurova. Further attempts may be made involving the concomitant use of herbivorous fish, with the cooperation of the General Directorate of Fishery Products.

Unpublished document WHO/EURO.
d. Larviciding measures were carried out by the malaria personnel, and in some instances by the municipality staff in urban areas of Chukurova and in special situations in other strata.

(2) Measures against the malaria parasites:

Surveillance activities were mainly based on active case detection (ACD). When compared with 1983 activities, it was realized that while the number of slides collected in 1984 by ACD remained almost the same, the number collected by passive case detection (PCD) decreased, and by activated passive case detection (APCD) increased. While more slides were collected in Stratum IV and less in Stratum I, there was a decrease in the total number of slides collected and slide positivity rate of APCD. Although less slides and less accuracy in identification were observed in 1984, health centres personnel showed progress in surveillance activities. Malaria treatment has been carried out as follows:

- Radical treatment (3 days chloroquine: total 1500 mg + 14 days primaquine, 15 mg/day).
- Mass radical treatment (same as above).
- Winter radical treatment (14 days primaquine, 15 mg/day).
- Single dose prophylactic treatment (600 mg chloroquine + 50 mg pyrimethamine/single dose).

It is believed that radical treatment has not been properly carried out, because of frequent interruption of therapy due to its long duration and has resulted in relapses. Prophylactic treatment could not reach the entire target population, and it was difficult to follow-up due to population movement. The problem of G6PD deficiency in Turkey has always been a major source of risk and entailed hesitation in giving radical treatment.

(3) PHC/MAL integrated approach:

There have been many constraints relatively specific to antimalaria activities, and some others that have been common to PHC services in Turkey as shown in the following:

a. Shortage of man-power (e.g., malaria workers) has decreased to a great extent the effectiveness of 1984 activities. Although 2700 new workers were recruited in 1984, the delay in their appointment, their training and distribution to health centres, as well as the lack of experience of health centres to carry out specific antimalaria activities, have created problems.

b. Inadequacy of the amount of insecticides purchased for 1984 operations and the man-power to apply the available quantities have been the main reason that contributed to inadequate dosages, rounds and spraying coverage.

c. Integration of the services that began in 1984 has created a certain degree of confusion at field and central levels. The integration of an entirely vertical programme into a horizontal one, which by itself is in the phase of development, has certainly been a difficult but a fundamental step. There will be a mutual adaptation of the malaria and PHC staff in the way of their training, implementation and supervision of integrated activities.

d. Lack of proper training has been one of the most important issues not only for the antimalaria activities but also for PHC services. Regular training on malaria has been carried out for medical officers, laboratory technicians and personnel directly involved in specific antimalaria activities.

e. Transport has been the common problem for all PHC services. Most of the health centres do not have adequate transport facilities (vehicles, gasoline, or drivers) which reflected on their performance of antimalaria activities, resulting in delays in transportation of slides, feedback and supervision.
f. Evaluation has not been carried out sufficiently. This has been mainly due to the lack of adequate and relevant epidemiological knowledge and shortage of qualified staff. Evaluation from a central level of all field activities in the slightest detail, resulted in loss of time and efforts and caused inaccuracies in the evaluation.

g. Inadequacy of community participation and intersectoral cooperation has been a major constraint, creating adverse impacts in particular on source reduction activities. Intersectoral cooperation has been started a long time ago and resulted in effective modifications such as the construction of a dam dike by the State Hydraulic Works (DSI) but needs further improvement and strengthening. The same applies to community participation which is expected to benefit from massive and intensive health education planned to take place in forthcoming years.

h. Supervision of malaria activities was done by both PHC and malaria personnel which led to the problems of duplication at the beginning of integration.

i. Population movement as characterized by the seasonal movement of migrant workers in malarious areas, created a huge mobile reservoir of infective cases. Because they are not residents, migrant workers are not registered, followed up or controlled by health centres, even though they live in the same catchment area.

j. Lack of research facilities may lead to the risk of inability to follow the trends of the impact of control measures on the parasite and the vector.

Comments and proposals for 1985 plan of action:

It was strongly emphasized that considering the designed strategies versus the actual financial allocations, which determined the amount of insecticide available (40% of the amount required), it will be rather difficult, if not impossible, to reach the target of " Interruption of malaria transmission in Turkey by 1989". Therefore, attention was drawn to the urgent need for increasing the budgetary allocations for PHC activities including malaria control. Even if this requirement is met, the strategies should be changed, priorities should be set for programme activities and areas with the redistribution of resources, based on analysis of risks, bearing in mind that the programme is meant to be a control programme and not an eradication campaign. This should be done to achieve the target. The change which may involve some risks, calls for an urgent political commitment.

Health services in Turkey are passing through a transitional period: vertical services are inevitably being integrated into a horizontal system which is in the process of development. Apart from priorities to be given to activities and increase in financial allocations, training appears to be the activity of highest priority to achieve this integration and reach the targets.

Comments and proposals for orientation of activities in 1985 were shown as follows:

(1) Antivectorial measures:

Residual house spraying remains one of the most effective antivectorial measures if done properly. The quantities of insecticides purchased for 1985 is not sufficient (240 tons), bearing in mind that the amount required for Stratum Ia alone is about 640 tons, and this calls for an urgent need for providing additional quantities of the insecticides. The expenses incurred may be provided by seeking supplementary resources, national or international. Care should be given to alleviate the complications of bureaucratic procedures that may delay the purchase of additional insecticide stocks. The amount of insecticides consumed in 1984 also would guide the manpower requirements. About 3 500 spraymen are needed to complete the spraying rounds, while there are 2 700 workers for all malaria activities, most of whom require training or retraining. The dosage applied is also very important. If the dose of 2 g/m² is not achieved, spraying can hardly be justified considering all the expenditure and efforts put into it. Additionally, shortening the time of spraying rounds is strongly recommended. Pirimiphos-methyl offers certain advantages over malathion, but a specific study is recommended to evaluate its effectiveness in certain areas, then it can be expanded to other areas watching for indications of failure. Partial spraying of houses and total spraying of stores and stables would be an effective strategy of application. Malathion may be used in areas where it is accepted and has proved to be effective.
Space spraying, winter fogging and ULV application may be discontinued. Also, biological control methods may be dropped unless the problems mentioned under (1)c are solved. Self-help measures such as the use of bed-nets impregnated with insecticides may be effective provided that the community is motivated to use such simple devices.

Larviciding should be carried out in urban and peri-urban areas with the direct involvement of municipalities, other related sectors and communities under the guidance of health personnel. Direct involvement of malaria and other health personnel in source reduction activities should be avoided. As in larviciding, a multisectoral approach should be observed in source reduction activities, with the chief efforts being made by the municipalities, other sectors such as DSI and community participation, under the guidance of health personnel. This would seem to be the most appropriate and effective strategies.

(2) Measures against the malaria parasites:

Every effort should be made to provide facilities for diagnosis and treatment of malaria cases. Case detection activities should be carried out by health personnel in all health institutions with special emphasis on PCD. ACD should be discontinued in malarious zones, bearing in mind that people are aware of malaria symptoms and will go to health centres whenever they have fever. PCD should be the main case detection activity; midwives and other health personnel, including laboratory staff as well as doctors working in hospitals should be trained to undertake proper malaria detection activities. Microscopes and vehicles may be redeployed to malarious zones for strengthening case detection activities. Treatment of all suspected malaria cases must be made after taking blood slides for microscopical examination. Radical treatment with 3 days of chloroquine (total dose 1.5g) + 5 days of primaquine (15 mg/day) would be most suitable. Long radical treatment always has the risk of interruption and/or failure. Mass radical treatment with the dosages described above may be reserved for migrant workers. In the presence of appropriate radical treatment activities, winter radical treatment is probably not warranted. Presumptive treatment may be dropped, and in places where antimalarial treatment on clinical diagnosis is needed, 1.5 g of chloroquine may be used under the name of clinically based treatment. This is probably not required in places with very low parasite incidence (as in Stratum IV). Chemoprophylaxis is unlikely to succeed on a long term basis, because it is dependent on its regularity, and may lead to dangerous levels of chloroquine accumulation. If chemoprophylaxis must be done, pyrimethamine may be deleted from the regimen.

As an overall plan for malaria control in Turkey, the meeting agreed on various activities that should be undertaken in each of the following areas:

(a) Urban areas:

- Larviciding: Direct involvement of municipalities, other sectors and the community with the technical assistance and guidance of health personnel would be the most effective strategy.
- Source reduction: same as above.
- Radical treatment of cases detected by PCD: promoting the use of health services and active involvement of personnel of health centres (HC) is required.

(b) Rural areas:

- Residual house spraying: good coverage supported by supervision of HC personnel is recommended.
- Radical treatment of detected cases: same as above.
- Chemoprophylaxis for migrant workers: health centres and mobile teams should play the major role.

N.B.: The above activities are meant for rural areas which are malarious (e.g., Chukurova). In areas where malaria is not a major problem, some activities can be deleted.
(c) Rural areas with development projects:

There are some rural areas where some development projects may have an important impact on malaria control activities (Lower Seyhan and Urfa). The main role of the Ministry of Health should be the guidance of the authorities and sectors involved in the projects.

(d) Tourist areas:

Municipalities should receive support from the Ministry of Health in the way of technical guidance and training of personnel in malaria control activities. Hotel managers, members of other private sectors and the community should actively contribute to malaria control in tourist areas. Activation of sanitation projects in tourist areas of the Mediterranean coast may give additional support.

The meeting underlined and emphasized the importance of two important aspects suggesting their improvements as follows:

- Information system: Some of the forms used for recording information on malaria and its control have been in use since the commencement of the malaria eradication campaign. There is an urgent need for simplification of these forms. In 1985, the same system will be inevitably used with few changes. With the establishment of the new PHC information system, the malaria control information system will also be taken into consideration. After establishing the new information system, modifications and updating should be made according to needs.

- Epidemiological investigations: The flow of information without careful epidemiological evaluation and investigation has little, if any, value. Epidemiological investigations should be directed to localities on the basis of priority (e.g., age-groups affected or appearance of malaria in a locality which previously had no infection) and should be carried out by qualified personnel. On this basis, in areas with a serious malaria problem such as Stratum I, epidemiological investigations should be carried out by the personnel of Communicable Diseases Control Division and malaria subdivision in the Provincial Health Directorate in order to analyze trends and monitor the problem in various localities. Epidemiological investigation of individual cases should be confined to Strata II-IV and carried out by qualified personnel. This is probably not warranted for Stratum I, and should be avoided to minimize loss of time and unnecessary utilization of resources.

The meeting further proposed a set of activities for each of the five epidemiological substrata as follows:

- Substrata Ia and Ib: High priority for full activities should be given to malarious zones as in Stratum Ia. It was the consensus of opinion that Stratum Ib should be considered just like Stratum Ia, bearing in mind that there is a potential risk arising from the Southeast Development Project (SEP), and that an epidemic will be harder to control in Stratum Ib than in Ia. Thus, ongoing activities should continue in Stratum Ib as in 1984, and residual house spraying be done in selected areas where malaria is an important problem. Malathion may be used on the basis of low community resistance to its spraying. Efforts in ACD may be modified as mentioned above.

- Stratum II: Special attention should be paid to areas with high risk based on social and ecological conditions. In other areas, vigilance should be instituted and active control operations may be discontinued. In tourist areas, a multisectoral approach as shown above would be the most effective strategy. Although migrant workers do not seem to create a special problem, vigilance should be instituted and Village Health Committees should monitor the movements of migrant workers. Personnel of health centres in those areas should be guided and motivated to provide proper health care and attention to migrant workers.

- Strata III and IV: Care should be given to the two strata by applying vigilance activities and epidemiological follow-up. Depending on local conditions, certain measures may be applied in 1985 if necessary.
Table 20. Malaria cases recorded in Turkey in 1987 from the five epidemiological strata.

<table>
<thead>
<tr>
<th>Period</th>
<th>Stratum</th>
<th>Indigenous</th>
<th>Re-lapse</th>
<th>Imported</th>
<th>Introduced</th>
<th>Induced</th>
<th>Gyptic</th>
<th>Unclassified</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>a</td>
<td>b</td>
<td>c</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st quarter</td>
<td>Ia</td>
<td>300</td>
<td>766</td>
<td>116</td>
<td>1</td>
<td>8</td>
<td>13</td>
<td>1183</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ib</td>
<td>5</td>
<td>142</td>
<td>380</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>1350</td>
<td></td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>10</td>
<td>2</td>
<td>20</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>2</td>
<td></td>
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<td></td>
<td>IV</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Total</td>
<td>315</td>
<td>914</td>
<td>527</td>
<td>5</td>
<td>13</td>
<td>13</td>
<td>1783</td>
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</tr>
<tr>
<td>2nd quarter</td>
<td>Ia</td>
<td>2255</td>
<td>631</td>
<td>159</td>
<td>1</td>
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<td>135</td>
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a = from abroad  b = from areas with or without antimalaria measures  
c = from areas in the consolidation phase
On the basis of all the above comments and proposals, the meeting made a series of conclusions and recommendations including the need for international support.

The most recent data on the malaria situation in Turkey in 1987 as communicated to WHO are shown in Table 20. The data show considerable reduction in the number of malaria cases amounting to about 36% of the total cases recorded in 1984 (55,000). Stratum Ia alone produced 11,733 cases constituting 58% of the total cases detected in all strata in 1987. About 34% of the total cases recorded in this stratum were imported from other endemic strata, representing the infection carried mainly by migrant workers. The data also indicate clearly that malaria transmission occurs chiefly in the 2nd quarters and reaches a peak in the 3rd quarter as already shown above.

Further information from Turkey became available just before the finalization of this document for reproduction. Akaba, Kasap & Kasap (1990? - in press) re-emphasized that each year more than 100,000 seasonal agricultural workers migrate to Cukurova area from southeast Anatolia. These workers sleep outdoors without bed-nets and usually neglect taking the antimalarial drugs delivered to them. During 1985-1989, pirimiphos-methyl was used for house spraying and temephos for larviciding. Chloroquine + primaquine for radical cure. Malaria cases reported from Cukurova mostly originate in Dogan Kent area where, as in other parts of Turkey, a significant reduction in malaria morbidity has been observed since 1985 (from 42.6/1000 in 1985 to 4.4/1000 in 1989). The morbidity among local inhabitants of Dogan Kent decreased from 56.6/1000 in 1985 to 2.1/1000 in 1989, but in migrant workers morbidity decreased from 27.2/1000 in 1985 to 7.2/1000 in 1989. However, the percentage of microscopically confirmed malaria cases greatly increased among migrant workers (from 30.5% in 1985 to 73.8% in 1989), while it decreased among local inhabitants (from 69.5% in 1985 to 26.9% in 1989). The malaria prevalence was high in summer reaching a peak in July, and the disease affected both sexes and age-groups.

Kasap et al. (1990? - submitted for publication) reported on village-scale trials with pirimiphos-methyl carried out to assess the effect of this insecticide currently used for house spraying in Cukurova area, against scharrovi population. The insecticide was applied as emulsifiable concentrate (EC) at dosages of 0.5 g/m² and 0.9 g/m², and as water dispersible powder (wbp) at a dosage of 1.6g/m². In each house, the living room, bedroom, kitchen and entrance/hall were partially sprayed, but the rest of the dwelling was sprayed completely; coverage was 69.7%. Entomological evaluation of these treatments comprised susceptibility tests, estimation of day-time indoor resting density of scharrovi, determination of parous rate and carrying out contact bioassays on eight different types of surfaces. An. scharrovi showed complete susceptibility to pirimiphos-methyl; the discriminating dosage that gave 100% mortality was 0.5% for 30 min. Pirimiphos-methyl applied at a dosage of 0.9 g/m² gave the best results for it produced an appreciable reduction in the parous rate, 96.9% reduction in scharrovi resting density, and more than five weeks residual effectiveness on lime wash and cement surfaces, and more than seven weeks on cement briquettes, wood, zinc, plywood and brick.

In Morocco, Guy (1963) analyzed the parasitological data collected during three years (1960, 1961 and 1962) preceding the establishment of the malaria eradication programme in 1963. Malaria was found in all districts at a varying degree of endemicity according to climatic conditions. The central plain region was the most endemic, followed in descending order of magnitude by the mountainous region, the pre-Saharan zone, the Atlantic coast, and finally the Mediterranean coast which was the least endemic. During the three years P. vivax ranged from 55.3% to 70.5%, P. falciparum from 14.2% to 28.6% and P. malariae from 15.3% to 18.5%. From the curves of monthly records of malaria cases, it was deduced that malaria transmission in the whole of Morocco extends from May to October with a peak in July, with the seasonal decline occurring in November. The season of P. malariae was found to be late, primary infections were not seen until July.

Benmansour (1972) noted that malaria in Morocco increased in 1971. The total number of blood slides collected in 1970 and 1971 was 119,439 and 118,956 respectively, the latter represented an annual blood examination rate (ABER) of 7.2%, whereas the optimum ABER in malaria eradication is 10%. The slide positivity rate rose from 0.48% in 1970.

1. Summaries of the two papers were kindly provided by Prof. H. Kasap (personal communication, January 1990).
to 0.94% in 1971, a nearly 2-fold increase. The majority of the positive slides came from sectors having previously been known to contain potential malaria foci which had not been subjected to DDT house spraying. The important factors that influenced the revival of these foci were as follows:

(a) Surveillance: Different medical missions indicated that surveillance activities were not functioning correctly during 1971, and even not carried out at all in certain sectors.

(b) Treatment of malaria cases: A good number of personnel responsible for antimalarial activities were charged with other duties during the malaria transmission season. Thus, they were not able to undertake radical treatment or carry out mass treatment correctly where it was deemed necessary.

(c) Rainfall: The year 1971 was exceptionally affected by excessive rainfall. The amount of rainfall in the rainy season (October-May) of a normal year (409 mm) was exceeded by about 183 mm in 1971. Moreover, the spring rainfall in 1971 was about 309 mm which is excessive for a normal year.

However, in all regions that have been subjected to DDT spraying, malaria transmission ceased or was considerably reduced, notably in Tetouan, Taza, Al-Hoceima and Tangier provinces. The plan of 1972 envisaged more systematic case detection and treatment of patients, training of new malaria microscopists, extension of DDT spraying, classification of water collections, installation of equipment for dispersal of larvicides by vehicle, drainage work, and entomological studies in many provinces.

Naji et al. (1985) analyzed the situation of imported malaria in Morocco. The classification of malaria cases as being imported has been a difficult task because of the uncertainty of local contraction of the infection. It has been fairly easy to exclude P. falciparum, P. ovale and P. malariae infections, as these had disappeared from Morocco before 1978. The difficulty remains with P. vivax, because the patients' cards do not give any indication of malaria episodes before departure from the endemic zone outside Morocco. From January 1978 to December 1982, it was possible to classify 140 cases as imported and 953 as autochthonous, thus the imported cases constituted 12.8% of the total cases recorded in Morocco during this period of five years. The number of imported cases steadily increased to 50 in 1980, but declined to 33 in 1981. The majority of imported cases were P. vivax and P. falciparum infections, respectively 67.85% and 26.42%, with one mixed infection of the two parasites (0.72%). P. ovale constituted 4.28% and P. malariae only 0.72% (1 case). Most of the imported cases originated from tropical Africa, notably Equatorial Guinea (97 cases) and Zaire (11 cases). Unlike the situation in Europe where immigrants constitute a large proportion of the imported cases as they contract the infection when spending holidays in their countries of origin, the Moroccans are themselves the main source of imported malaria as they contract the infection during their professional travel in tropical Africa. The decline in the number of imported cases in 1982 was attributed to better explanation of the value of prophylaxis provided to travellers. The lapse of time between the onset of malaria symptoms and the date of return to Morocco from an endemic zone was studied in 100 patients of imported malaria. The average period was 15 days for P. vivax and three months for P. falciparum, but there was a delay of one year in 4 cases (2 P. falciparum and 2 P. vivax). This would indicate that the period of continued prophylaxis for two months after return to Morocco would not be sufficient.

Synopsis of the malaria situation in Morocco during 1982-1985 was shown in SECTION I, under 2.1 in document VBC/90.1-MAL/90.1. From the recent information communicated to WHO/MAP, the data show the malaria situation in 1987 as follows: (Population given as a mid-year estimate in thousand).

- Total population: 23 376
- Population of originally malarious areas: 12 832
- Population claimed to be freed from malaria: -
- Population under malaria control programme: 12 832
- Population protected by house spraying: 109
- Population protected by other anti-vector measures (larviciding & biological control: 701
- Population under surveillance: 12 832
The epidemiological situation in 1987 was marked by resumption of malaria transmission in the old foci of Khouribga, Fès and Meknès, as well as an increase in the imported cases. Autochthonous cases were detected in the following provinces: Fès (227), Chefchaouen (169), Meknès (115), Khouribga (72), Larache (50), Tetouan (9), Beni Mellal (8), and El Hoceima (6), making a total of 656 cases in 1987. Compared with the total number of cases recorded in 1986, there was an increase of 42% in 1987. Nevertheless, the number of cases decreased by 34% in Chefchaouen, 20% in Beni Mellal, 70% in Larache, and 42% in Al Hoceima. In addition the number of cases decreased in two other provinces: by 75% in Kenitra and 40% in Khemissat. On the other hand, the number of imported cases increased considerably reaching over 600 compared with 97 in 1986.

In Algeria, the malaria eradication programme was started in 1968 and since then it has progressed satisfactorily except for certain problems which were investigated and dealt with in time. The report of the Ministry of Public Health, Algeria (1973) that was presented to the Antimalaria Coordination of Antimalaria activities in the Countries of Maghreb, 4–6 December 1973, showed that the Algerian malaria eradication programme during 1973 followed closely the Plan of Action of the 3rd addendum of the Plan of Operation as follows:

- Annaba Wilaya (Department): 2nd year of consolidation phase.
- Constantine and Aures Wilayat (Plural of Wilaya): 2nd year of attack phase.
- Setif and Tizi-Ouzou Wilayat: 2nd year of attack phase.
- Alger, Ttleri and El-Asnam Wilayat: preparatory phase.

In the rest of the country, the classical malaria control activities continued especially the focal spraying in the more malarious zones in order to limit the extension of the important foci which were detected in 1972. As in previous years, 1973 was quite favourable for malaria transmission, particularly at the end of summer in the littoral strata. The epidemiological data obtained in 1973 up to October from all territories confirmed the favourable evolution of the malaria situation in all the regions under the eradication programme, but recrudescence of malaria transmission occurred in the rest of northern Algeria despite the application of DDT spraying protecting more than 380 000 inhabitants living in the more endemic foci. The report outlined the various activities and the results recorded in each Wilaya. Briefly, the epidemiological situation up to the end of October 1973 was summarized as follows:

(a) In regions under the malaria eradication programme:

- Total population of Algeria: 15 000 000
- Population protected by attack measures or surveillance activities of malaria eradication operations: 6 500 000
- Population protected by DDT spraying: 2 830 000
- Slides examined: 292 245
- Slide positivity rate (SPR): 0.018% (53 positive slides)

All the cases were P. vivax, but six cases were classified as autochthonous. None of 5281 slides examined from infants were positive. Thus, the evolution of the epidemiological situation in the vast majority of the Algerian territory in 1973 was satisfactory and the regression of infection from SPR of 0.49% in 1971 to 0.07% in 1972 and to 0.018% in 1973 provided evidence of the efficacy of malaria eradication measures.

(b) The rest of the country: The remaining part of the country that was not covered by malaria eradication operations constituted almost the western half of northern Algeria, and the Saharan region, with a total population of 8 000 000 inhabitants, of whom about 3 000 000 were under malaria risk. The plan of action of 1973 envisaged diverse measures aiming at reduction of the foci detected following the epidemic exacerbations that

1. Permission to use information contained in this report was granted by Dr E.H. Benzerroug, Division du Paludisme et des Maladies Parasitaires, Institut National de Santé Publique, Alger.
occurred in the summer of 1972, principally in the Wilayat of El-Asnam and Mostaganem. The measures were as follows:

- DDT house spraying to protect more than 380,000 inhabitants.
- Activation of PCD.
- Presumptive treatment.
- In regions where cases were rare, epidemiological investigations were carried out and radical treatment given.
- Anopheline measures and barrier spraying in the north of Tlemcen and in the border zones of Morocco.
- Mass investigations.
- Subsequently typical preparatory phase activities were implemented in the Wilayat of Alger and El-Asnam.

As mentioned above, the year 1973 was quite favourable for malaria transmission, particularly in the Mediterranean zones, and despite the application of these measures the malaria incidence continued to increase in the western and southern zones. The number of cases detected in 1972 was around 2000, but in reality the number much exceeded this figure. In 1973, the number of relapses was high, and when the number of new cases was added to it, the total number of cases detected in the territories not submitted to malaria eradication operations exceeded 3000. Of these, 11 were reported from the Saharan region. No cases were recorded in Tlemcen Wilaya, despite the presence of epidemic manifestations in the neighbouring province of Oudja in Morocco. This provided evidence that the measures applied in this Wilaya were effective. Regarding *P. falciparum* infection in all areas, it markedly regressed to 29 cases and 2 mixed in 1973 from 91 and 6 mixed in 1972.

In conclusion, the following points were underlined:

(a) The malaria eradication programme in Algeria has given good results despite many difficulties especially those of an administrative nature which affected the smooth running of the operations. In the Wilaya of Annaba which was in the second year of the consolidation phase, transmission was resumed in Berrahal (Da'ira of Annaba) giving rise to a total of eight cases, of which four were introduced. The necessary remedial measures were applied and pursued.

(b) In the Wilayat under the attack phase, the evolution of the epidemiological situation was satisfactory, but great efforts were needed in order to ensure total coverage of the population by surveillance activities, so that these Wilayat can safely pass into consolidation phase.

(c) In the western part of northern Algeria, which has not been covered by malaria eradication operations, control measures applied certainly prevented the explosion of serious malaria epidemics from a large reservoir of infective cases that existed during the favourable conditions for transmission in the past two years.

(d) The progressive decrease of the susceptibility of *labranchiae* to DDT makes it necessary to cover urgently the areas of north Algeria not included in the malaria eradication programme, before DDT resistance becomes an insurmountable problem. For this reason, the plan of action of 1974 envisaged the initiation of the attack phase in the Wilayat of Tittereri, Alger, El-Asnam and Mostaganem, and total coverage spraying in all foci discovered in the last two years in the Wilayat of Oran, Tlemcen and Tiaret.

Ramsdale (1975) in a mission to Algeria during July-August 1975 tested the susceptibility of *labranchiae* to DDT in different areas sprayed recently or for a number of years previously with DDT. The tests showed that the increased tolerance to DDT observed in 1970 and 1972 seems to have stabilized. This was probably due to the progressive reduction in the use of DDT in agriculture following the decision made by the Ministry of Agriculture. This cooperation would be extremely valuable for the antimalaria programme as it permits the conservation of DDT for house spraying over a prolonged period in areas under attack or in case of revival of transmission in certain foci in areas under the consolidation phase.

Oddo (1981) in his unpublished report to WHO on a mission to Algeria during November 1981 to assist in the evaluation of the epidemiological situation of malaria and in
drawing a plan of action for 1982, described the development of a malaria outbreak of
*P. vivax* in the health sector of Meftah, Khemis-el-Khechna locality, Wilaya of Blida, and
two cases also of *P. vivax* in the health sector of Thenia in the adjacent Wilaya of
Alger. The appearance of the focus of Khemis-el-Khechna was surprising to the authorities
of the antimalaria programme, because it occurred in a territory which had been free of
malaria under the consolidation phase for about 10 years since the termination of the
attack phase. The zone of this focus was situated in the valley of Oued el-Hamiz, a river
which descends from the northern slopes of the Mediterranean Atlas and pours into the sea
after traversing the Algerian littoral plains Métédia, formerly known to be a highly
malarious zone in northern Algeria. The area affected was situated in the terminal
portion of the middle section of the river, just before it enters the plain. In the upper
part of the river, there is an artificial barrage with its reservoir supplying the
irrigation system in Métédia plain. In this area, there were 16 agglomerations having a
sedentary population of 3,147 inhabitants with Khemis-el-Khechna being the principal
locality. The first malaria case of *P. vivax* appeared in July 1980, and a further case of
the same infection was detected in the Cité des Iris, health sector of Reghaia, Alger
Wilaya in September 1981. Through an epidemiological investigation made by the
epidemiology section of the Bureau Central d'Eradication du Paludisme (BCEP) and the
preventive team of health sectors concerned, 48 more cases of *P. vivax* were detected
making a total of 50 cases distributed in 10 of the 16 localities of the valley. The
distribution of the cases indicated that the epicenter of the epidemic was in the area of
three contiguous localities: Ammiria, Barrage and La Cave, where the initial infections
were contracted about the beginning of the transmission season in June 1980.
Subsequently, transmission occurred in the other seven localities of the valley before the
introduction of remedial measures. It was clear that the evolution of this
epidemiological situation arose from the revival of a parasite reservoir which
unfortunately remained undetected because of the failure to examine microscopically about
2,000 blood slides which could not be traced later. On the other hand, there was a fairly
high number of asymptomatic parasite carriers (8 out of 50) who probably remained unknown
in the previous years. The centre of this epidemiological manifestation appeared to be
the locality of Ammiria which was composed of flimsy scattered structures and inhabited by
seasonal workers who came from regions of the high Algerian plateaux, notably from the
Wilaya of M'dila. This raises the question whether these migrant workers acquired the
infection through their mobile mode of life or in their place of origin. Longitudinal
case detection carried out for many years in the Wilaya of origin of these workers
(M'dila) has not revealed any indigenous case of malaria. Nevertheless, it should be
remembered that the region of the high plateau used to be regarded by former
malariologists as the "château d'eau" for malaria.

Benzerroug & Wéry (1985) carried out a seroepidemiological investigation in the focus
of Khemis-el-Khechna during 1984 to ascertain the efficacy of control measures applied for
three successive years. This focus yielded the majority of the autochthonous cases
recorded in 1981 in Algeria (51 out of a total of 53 cases), all of which were *P. vivax*.
Control measures comprised: radical treatment of the 51 positive subjects; 7-day treatment
of 250 collaterals; and DDT spraying of all houses in the focus for three years,
1981–1983. Through surveillance 18 cases were detected in 1982, of which 4 were
classified as relapses, and no autochthonous cases were recorded in 1983. The objectives
of the seroepidemiological investigation of 1984 were:

(a) estimation of the seropositivity rate and comparing the results with those of
parasitological investigations carried out in the localities of the focus;

(b) analysis of the seropositivity rate by age-group, and assessing the changes in
its levels (before and after the transmission season);

(c) comparing the serological results obtained with two blood sampling techniques:
serum on filter paper and eluted dried blood, and determining the differences between two
antigens used in IFA test, viz: *P. falciparum* culture strain, and *P. vivax* strain from a
patient originating from India.

Briefly the results led to the following conclusions:

- the superiority of the seroepidemiological study over the parasitological
  examination in the analysis of the situation in the previous malaria focus of Khemis El
  Khechna was demonstrated.
- The analysis of the serological findings by age, locality, and time provided evidence that the reservoir of infective cases was eliminated and transmission completely interrupted. At the same time, 470 blood slides examined parasitologically were all negative.

- Comparison of the serological results obtained by two blood sampling techniques confirmed the reliability of the method of collecting blood on filter paper.

- Comparing between the antigens revealed that the proportion of seropositive samples was significantly higher \((P < 0.001)\) when \(P. falciparum\) antigen was used compared with \(P. vivax\). This poses the problem of the level of sensitivity of \(P. vivax\) as antigen originating from a different geographical area.

To investigate this problem, Benzerroug, Demedics & Wéry (1986) made a double-blind serological study on 16 sera sampled from the above-mentioned Khemis-el-Khechna focus of \(P. vivax\) in Algeria, and 7 sera from patients with proven \(P. vivax\) infection contracted in India. The reactivity of each of these serum samples was tested by IFA test using different batches of antigen, including 3 batches of \(P. vivax\) antigen prepared with isolates from Zaire, Africa, India and Solomon Islands respectively. For the detailed results the original paper should be consulted, as it is sufficient here to give the highlights of the findings as summarized by the authors. Among the 15 samples from Algeria, the percentage of seropositives decreased from 100\% using the homologous antigen originating from the same continent (Africa) to 86.6\% using the homologous antigen from the Solomon Islands and further to 63.3\% using the homologous antigen from India. Based on the results of this study, two aspects were underlined:

- In seroepidemiological studies, sensitivity could be improved by the use of a homologous antigen from the same geographical origin;

- In detection of clinical cases of malaria and species identification based on serology, the present results point to the need for caution in interpreting serological titres and for taking into account the geographical origin of the isolates used as antigen.

The Saharan region of Algeria has received attention in the past and in recent years. Of the early studies, reference is made to a report by Lefèvre-Witier (1968) describing an epidemic of malaria in Tassili N' Ajjer during 1965. Tassili N' Ajjer is an area situated between 23° and 26° N latitude and between 5° and 12° longitude, forming the northeastern part of the sandstone plateau which surrounds the volcanic massif of Hoggar. The climate of Tassili N’Ajjjer differs from that of Hoggar in that it is influenced by the Sahel. It is very dry and has a continental climate. Rainfall at the foothills of the plateau is about 15 mm/annum on an average, mostly falling in one or two bouts of violent thunderstorms during the hot season, but in the absence of actual measurements, the amount of precipitation is probably double. The mean minimum temperatures are between 4 and 6°C in January in the areas surrounding the plateau, but range from 1 to -5°C on the plateau itself. The autumn (September-15 October) is as hot as in summer, but subsequently cold weather prevails. The mean maximum temperature reaches 40°C in Djanet. Vegetation is represented by poor pasture, as in Hoggar. Some well watered zones support relict of Mediterranean flora. At the time of the investigation, the population consisted of 10 000 inhabitants, about 1/3 of whom were concentrated in Djanet oases, which is the administrative capital situated at the foothills of the plateau. The other 2/3 was composed of semi-nomads who exploited some micro-centres for cultivation, and nomads who owned nothing but their herds. Among the cultivation centres in Tassili, two were typical: Aharar and Ihérrir, located at the basaltic foothills of Adrar. They were the most important centres of resurgence of malaria. In fact, it was at Ihérrir (with 200 inhabitants) that a wave of a malaria epidemic was observed. During the first mission to Tassili N' Ajjer in April 1965, no larva or adult mosquitos were found, but towards the end of September of the same year, mosquitos became numerous and many fever cases were found. At the beginning of October, a survey was conducted for one week, during which period the spleen index was established, blood films were collected from children and adults encountered, presumptive treatment given according to age (nivaquine + pyrimethamine), and larvae of mosquitos collected. The findings supported by tabulated data showed the following:

(a) The overall spleen index (children and adults) was about 15\%.
(b) Of 21 children (age-group 0-5 years) 18 were positive; of 13 children (5-10 years) 13 were positive; and of 83 persons (10+ years including adults) 47 were positive (57%). The parasite species identified in the 74 positive slides were: 90.5% P. falciparum, 2.7% P. vivax, 2.7% P. malariae and 4.1% mixed (P.f. + P.m.). Thus, it seems that P. falciparum was responsible for epidemics at this latitude, particularly in Tassili N'Ajjer. These results also indicated that children were the most affected at Iherir, but there were no deaths. On the other hand, there was not a single case of pernicious manifestations encountered. Enquiry from the inhabitants and the study of medical reports and publications concerning this region, showed the existence of favourable climatic conditions for the development of repetitive seasonal waves of malaria. Taking into account the high probability of contraction of P. falciparum infection annually, the clinical picture that was observed at Iherir must have been due to the development of a certain degree of immunity. Contrasting with this presumption of the population of Tassili, the severity of clinical manifestations due to P. falciparum were rare among the populations of other regions of the central Sahara.

(c) The larval collections showed the presence of multicolor, a species known to breed in saline waters and this was confirmed at Iherir. Reference was made to some old records obtained from the Saharan region. While multicolor was reported from Iherir in 1941, only d'thali was found in this locality in 1958, but in the adjacent locality of Aharar sargentii together with hispaniola were encountered. In contrast, sargentii was found in association with multicolor and hispaniola in Hoggar, but this species association was never found in Tassili N'Ajjer. In 1929 when a malaria epidemic broke out at Djanet, Anopheles rufipes brusselesi was identified from this locality and also from Aharar. An. gambiae s.l. has never been observed in Tassili N'Ajjer.

(d) In view of the geographical differences, the problem of malaria and its control in the oases of Djanet must be distinguished from that of the localities dispersed on the plateau. In Djanet, control measures that have been applied for a long time consisted of constant surveillance of irrigation basins and channels (séguias) (clearing of vegetation and emptying every 10 days), besides which house spraying with lindane, larviciding and filling in of depressions and abandoned séguias. On the plateau, the measures that have been adopted since 1946 consisted simply of the administration of chloroquine to persons encountered by medical officers and the distribution of Gambusia affinis holbrooki in gueltas (ponds) of Iherir. It was impossible to carry out the measures of clearing vegetation, spraying of houses or treatment of breeding places; the accessibility of most of the cultivation centres has been extremely difficult. In conclusion, the author pointed out that in the mountainous part of Tassili N'Ajjer, there exists an annual rhythm of aestivo-autumnal malaria with light variation according to the amount of rainfall. The majority of nomads and semi-nomads are the victims, while the inhabitants of Djanet oases have been relatively protected for the past 50 years. In the other regions of the central Sahara whether mountainous or not, malaria manifests itself in severe epidemics due to contraction of infection through movement of the population for animal raising or for trade. The nomads of Tassili N'Ajjer are in permanent contact with the neighbouring regions of Hoggar, Ouargla and In Salah in Algeria; Tibesti in Chad; Ghudamis and Fezzan in Libya; and Adrar in Niger. The focus of Tassili N'Ajjer deserves profound studies because of the danger of dissemination of P. falciparum in Algeria.

Holstein et al. (1970) who described the anopheline fauna of the Algerian Sahara (see under 2.5 above) remarked that malaria endemicity is weak in this region, with the exception of a few villages with cultivation in Tassili and Hoggar. In these two areas, malaria is mesoendemic with annual recrudescence in the autumn. Still, the proliferation of the vector under exceptional climatic conditions could bring about epidemic episodes. These epidemics were studied in the past by different authors as they were revealed to be extremely serious causing high deaths. The parasite involved being P. falciparum in 90% of the cases provides an indication of its importation from an African origin. As shown under 2.5, the authors considered the responsible vector is sargentii, but multicolor was suspected by some workers. Thus, it was recommended that studies should be concentrated on sargentii during its season of abundance, September-November.

Zulueta & Ramsdale (1975) who surveyed some localities of the Algerian Sahara during October-November 1975 (see under 2.5 above), provided information on the malaria situation prior and during their visit. Yearly records of blood examination were tabulated covering the period 1966-1975 for the following localities: Ouargla, Djanet, El-Golea, El-oued,
Ghardaja, In-Salah, Laghouat, Tamanrasset, and Touggourt. Similar records were also given for two other localities: Adrar and Timimoun but only up to 1975. From these data, there were only three *P. vivax* cases out of 5611 slides examined from the first group in 1974, two of which came from Ouargla (658 slides examined) and one from In-Salah (1696 examined). In the same year, none of 198 and 2704 slides examined from Adrar and Timimoun respectively were positive. In 1975, all 3 836 slides from the first 8 villages were negative. In the authors' survey carried out during November 1975, none of 863 slides collected from Silet (Tamanrasset Wilaya) and Djanet and Ihéir (Ourgla Wilaya) were positive, although the blood examination rate of all age-groups including infants was 13.8% of a total population of 6 250 inhabitants, and sampling included fever cases and a population originating from Mali. The authors tried to find an explanation for the absence of infection in their survey. It is generally accepted that in the oases of the Sahara, flare-up of malaria transmission occurs for a brief period following increased precipitation. This was confirmed by the finding of 170 cases of *P. falciparum*, 56 *P. vivax* and 2 mixed in 1969 at Timimoun (1685 slides examined), citing Maruto & Fellahi (1969). From the available meteorological data (Tamanrasset station), the annual mean rainfall in a normal year is 37.6 mm. The authors' survey was carried out in a nearly normal year when the annual mean rainfall was 32 mm in 1975 and the preceding year 31 mm. This assumption was supported by the fact that the density of anophelines during the authors survey was very low, except at Ihéir, in which the investigation could not be pursued (see under 2.5 above). Further blood surveys covering 20% of the population to be carried out in the favourable season (September–October) simultaneously with investigation on the biometrics of *sergentii*, preferably at Ihéir were recommended.

Recently, Benzerroug & Janssens (1985) presented the malaria situation in Algeria with special emphasis on the Saharan region. The malaria eradication programme succeeded in reducing the annual incidence from about 100 cases/100 000 inhabitants in 1968 to less than 0.5/100 000 from 1976 onwards. In the last few years, the epidemiological situation was characterized by the persistence of residual foci of transmission in the northern part of the country (see studies of Kheis-el-Rhechna above), and the detection of an increasing number of cases in the Saharan region. The progress of the malaria eradication programme in the northern part of the country, the development of the health services and the establishment of specific antimalaria infrastructure in different Wilaya contributed to amelioration of surveillance activities. Simultaneously, frequent field malarimetric and entomological investigations have been carried out. The reinforcement of the surveillance activities arose from the need for extending the benefits of the malaria eradication to all parts of the country, and for preventing the risk of re-introduction of malaria transmission that may arise from movement of the population through the trans-Saharan route connecting Algeria with countries of south of the Sahara. The Saharan region which covers about 2 million square kilometres in Algeria, has been protected by classical antimalaria measures (see above), and those foci which are detected, receive reinforced measures. For assessment of the epidemiological situation in this region, the following sources of information were utilized:

- active case detection activities undertaken by the health services of the Saharan region, as well as the results of different malarimetric investigations;

- the entomological findings obtained during missions undertaken in different areas of the Sahara;

- statistical data concerning the movement of the population and traffic as recorded at the principal frontier posts of south Algeria (see under 2 below).

To compare between the northern and southern regions of Algeria, the annual parasite incidence in the two regions covering the period 1977–1984 were tabulated as shown here in Table 21(a), and Table 21(b) which shows the classification of the cases recorded in the Saharan region during the same period.

Table 21(a) Annual parasite incidence in northern and southern Algeria.

<table>
<thead>
<tr>
<th>Year</th>
<th>Region</th>
<th>Population</th>
<th>No. cases</th>
<th>Incidence/100 00</th>
<th>Ratio (S/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>North</td>
<td>16 412 330</td>
<td>15</td>
<td>0.091</td>
<td>64.40</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>733 670</td>
<td>43</td>
<td>5.860</td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>North</td>
<td>16 887 106</td>
<td>14</td>
<td>0.082</td>
<td>25.84</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>754 893</td>
<td>16</td>
<td>2.119</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>North</td>
<td>17 452 339</td>
<td>47</td>
<td>0.269</td>
<td>12.85</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>780 161</td>
<td>27</td>
<td>3.460</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>North</td>
<td>17 975 908</td>
<td>11</td>
<td>0.061</td>
<td>51.00</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>803 566</td>
<td>25</td>
<td>3.111</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>North</td>
<td>18 515 187</td>
<td>57</td>
<td>0.307</td>
<td>3.91</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>827 671</td>
<td>10</td>
<td>1.208</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>North</td>
<td>19 070 640</td>
<td>46</td>
<td>0.241</td>
<td>12.16</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>852 503</td>
<td>25</td>
<td>2.932</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>North</td>
<td>19 682 605</td>
<td>10</td>
<td>0.050</td>
<td>72.88</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>878 078</td>
<td>32</td>
<td>3.644</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>North</td>
<td>20 273 083</td>
<td>7</td>
<td>0.034</td>
<td>81.17</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>904 420</td>
<td>25</td>
<td>2.760</td>
<td></td>
</tr>
</tbody>
</table>

From the above data, it can be seen that of 410 cases recorded in the whole country during 1977-1984, 203 or about 50% came from the Saharan region. The annual incidence was at least 10 times higher in the south, and it even increased to about 80 times in 1984. The increase of incidence in the north in 1981 was due to resumption of transmission in the residual focus of Khemis-el-Khechna.
Table 21(b). Classification of malaria cases recorded in the Saharan region of Algeria during 1977-1984.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Indigenous No. cases</th>
<th>%</th>
<th>Imported No. cases</th>
<th>%</th>
<th>Unclassified No. cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>43</td>
<td>43</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1978</td>
<td>16</td>
<td>8</td>
<td>50</td>
<td>8</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>1979</td>
<td>27</td>
<td>15</td>
<td>55.5</td>
<td>10</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>1980</td>
<td>25</td>
<td>3</td>
<td>12</td>
<td>22</td>
<td>88</td>
<td>-</td>
</tr>
<tr>
<td>1981</td>
<td>10</td>
<td>1</td>
<td>10</td>
<td>8</td>
<td>80</td>
<td>1</td>
</tr>
<tr>
<td>1982</td>
<td>25</td>
<td>8</td>
<td>32</td>
<td>15</td>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td>1983</td>
<td>32</td>
<td>12</td>
<td>37.5</td>
<td>13</td>
<td>40.6</td>
<td>7</td>
</tr>
<tr>
<td>1984</td>
<td>25</td>
<td>4</td>
<td>16</td>
<td>21</td>
<td>84</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>203</td>
<td>94</td>
<td>46.3</td>
<td>97</td>
<td>47.8</td>
<td>12</td>
</tr>
</tbody>
</table>

The unclassified cases amounted to 5.9% of the total cases and could not be determined due to inadequate epidemiological investigations. The number of the indigenous cases was nearly equal to that of imported cases. Of the 94 indigenous cases recorded during 1977-1984, 64 or 68% were P. vivax detected in Ouargla oasis which constituted the principal focus of malaria in the Sahara and received special control measures until transmission ceased in recent years. These cases were recorded in 1977 (43 cases), 1978 (7 cases) and 1979 (14 cases), but none were detected in this oasis from 1980 to 1984. Of the remaining indigenous cases, 26 came from Adrar Wilaya which were identified as 19 P. malariae and 7 P. vivax. There were also two cases of P. vivax recorded in In Salah only in 1984. The identification of the 97 imported cases recorded during 1977-1984 showed that 65 (67%) were due to P. malariae, and 1 (1%) to P. ovale. The origin of infection of the imported cases was determined as 88.7% from Mali and Niger, 1% from each of Senegal, Benin, Tanzania and India, but the origin of the remaining 7 cases could not be determined.

Regarding the entomological findings, several investigations pointed to the presence of six Anopheles species in the Saharan region: multicolor, sergentii, d'thali, hispaniola, rhodesiensis rupicolus and rufipes broussesi. The presence of labranchiae in the Saharan region of Algeria based on only two specimens collected by early workers was doubted as being due to misidentification - see under 1.5 above. The authors referred to the widespread distribution of multicolor which had been suspected in the past as a malaria vector in Algeria. Recalling the views of Holstein et al. (1970) the role of this species in malaria transmission is debated on account of its presence all the year round in oases where malaria transmission is absent (see under 4.5 above). Thus, sergentii has been considered the principal vector of Saharan malaria. Reference was also made to the suggestion of Ramsdale & Zulueta (1983) that sergentii in the Sahara could consist of two species sergentii s.s. and sergentii macmahoni with the former being possibly the vector of malaria (see under 2.5 above). However, the results of recent entomological surveys conducted during 1980-1984 provided evidence that sergentii as well as multicolor existed in localities where autochthonous cases of malaria were detected, hence the role of each of these two species is as yet to be determined. The authors further underlined that An. gambiae s.s. has so far not been found either in the southern border area nor in the rest of the Sahara.

Benzerroug (1985) following the appearance of chloroquine resistance in P. falciparum in Tanzania, arranged for an epidemiological investigation on a group of 80 workers (Algerians ?) by teams sent to Tanzania for six weeks with the cooperation of the Tanzanian authorities. During 1982, these workers stayed in the island of Songo Songo from January to April, and in Kibidji province in Tanzania from May to December. From May to November 1982, 16 cases were suspected to have contracted malaria, of whom there were:
7 cases confirmed by the BCEP laboratory;
3 cases hospitalized and confirmed as P. falciparum infections by Claude Bernard hospital in Paris after a stopover in France;
6 cases were found negative after confirmatory examination.

Detailed data were tabulated showing the age and sex of each of the seven confirmed cases, their place of residence in Algeria, date of onset of illness, date of blood examination, parasite species and density, quantity of chloroquine received in November 1982, date of microscopical examination after treatment and parasite density. From these data, the author summarized the findings as follows:

(a) the predominant parasite was P. falciparum, as only one P. vivax was diagnosed;
(b) the first case was detected in May 1982, but the remaining cases were diagnosed later according to the date of appearance of symptoms;
(c) the patients' residence in Algeria were diverse, 7 Wilayat out of 31;
(d) two patients were found to be gametocyte carriers, of whom one received in May 1982, 1650 mg chloroquine without parasitological evidence;
(e) after several parasitological examinations following the treatment given in November 1982, one patient was regarded as the carrier of a P. falciparum chloroquine resistant strain as proved by the standard in vivo test (R II). The history and follow-up of this patient until cured was given in detail.

The majority of the patients declared that they were taking chloroquine prophylaxis at a minimum dosage of 300 mg/week during their stay in Tanzania. In conclusion, the author stressed the need for careful surveillance of imported cases for detecting chloroquine-resistant P. falciparum which constitute health hazards to the patient himself and the community particularly in countries where malaria eradication has been achieved or progressing towards its goals as in Algeria. The problem of imported malaria would call for strengthening vigilance, taking into account the receptivity and vulnerability of different areas.

Synopsis of the malaria situation in Algeria during 1982-1985 has been given in SECTION II, under 2.1 in document VBC/90.2-2. From the data communicated to MAP/WHO, the most recent malaria situation in Algeria is shown in Table 22.

These data show that of 63 cases recorded in 1987, 11 were classified as indigenous, 1 induced and 52 imported. All the imported cases gave a history indicating that their infections were acquired in tropical Africa, with the exception of one case (P. vivax) which showed travel to India. Of the indigenous cases, 3 were recorded in the southern oases under reinforced control measures, and 8 were in the north in areas under the maintenance phase situated in seven Wilayat. The two indigenous cases of P. vivax detected in the 3rd quarter of 1987 in Guelma and Djelfa respectively actually contracted the infection while camping at Guerbes locality in sector Azzaba of Skikda Wilaya under maintenance/consolidation. Epidemiological investigation in this locality led to the conclusion that a residual focus existed for which remedial measures were implemented. During a mass blood survey conducted in the 4th quarter of 1987, another case of P. vivax was discovered in this focus. To assess the efficiency of PCD, the ABER was calculated as 0.64% (73 991 inhabitants) in the 1st quarter, 0.56% (6 449 inhabitants) in the 2nd quarter, 0.51% (58 813 inhabitants) in the 3rd quarter and 0.57% (65 848 inhabitants) in the 4th quarter 1987. The low surveillance activities in the 3rd quarter was attributed to the absence of epidemiological information from Batna Wilaya and an insufficient number of blood slides collected from the Wilayat of Annaba, Laghouat, M'Sila, Constantine, Oum-el-Bouaghi and Alger. In the 4th quarter 1988, only 11 cases were recorded, all of which were classified as imported from tropical Africa mostly detected in the areas of reinforced control in the south.

In Tunisia, base-line studies conducted during the pre-eradication surveys that started in June 1957, as described by Werndorfer (1973), showed that the whole country was under malaria risk. Some hypoendemic foci were located in the northern and central parts of the country, while the endemicity in the remaining areas varied from meso- to hypoendemic levels. The malaria transmission season was found to extend from May to the beginning of November. Regarding the species of the malaria parasites, P. vivax was prevalent in the north, followed by P. falciparum and P. malariae, while in the central and southern zones P. falciparum and P. vivax occurred in nearly equal proportions, but P. malariae was virtually absent. The principal vector was labranchiae in the northern
Table 22. Malaria cases recorded in Algeria during 1987 and the first quarter of 1988.

<table>
<thead>
<tr>
<th>Wilaya &amp; date</th>
<th>Phase</th>
<th>Indigenous</th>
<th>Relapse</th>
<th>Imported</th>
<th>Induced</th>
<th>Unclassified</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Jan-Mar 87</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alger</td>
<td>Maintenance</td>
<td>-</td>
<td>-</td>
<td>2 P.f.</td>
<td>-</td>
<td>-</td>
<td>Imported from Mali, resident in Constantine</td>
</tr>
<tr>
<td>Constantine</td>
<td>1P.m.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adrar</td>
<td>Reinforced control(south)</td>
<td>-</td>
<td>-</td>
<td>3 P.f.</td>
<td>-</td>
<td>-</td>
<td>Imported from Mali</td>
</tr>
<tr>
<td>Tamanrasset</td>
<td>1P.m.</td>
<td>-</td>
<td>-</td>
<td>1 P.f.</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>4 Wilayat Total</strong></td>
<td>1</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>II. Apr-June 87</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alger</td>
<td>Maintenance</td>
<td>-</td>
<td>-</td>
<td>1 P.f.</td>
<td>-</td>
<td>-</td>
<td>Algerian</td>
</tr>
<tr>
<td>Bejaia</td>
<td>1P.o.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>French national detected at Bejaia</td>
</tr>
<tr>
<td>Adrar</td>
<td>As above</td>
<td>-</td>
<td>-</td>
<td>1 P.m.</td>
<td>-</td>
<td>-</td>
<td>Algerian in Timimoun</td>
</tr>
<tr>
<td>Tamanrasset</td>
<td>1P.f.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Algerian</td>
</tr>
<tr>
<td></td>
<td><strong>4 Wilayat Total</strong></td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>III. Jul- Sept 87</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alger</td>
<td>As above</td>
<td>-</td>
<td>-</td>
<td>6 P.f.</td>
<td>-</td>
<td>-</td>
<td>Algerians travelled to tropical Africa and Brazil</td>
</tr>
<tr>
<td>Tamanrasset</td>
<td>1P.v.</td>
<td>-</td>
<td>-</td>
<td>1 P.v.</td>
<td>-</td>
<td>-</td>
<td>French travelled to India</td>
</tr>
<tr>
<td></td>
<td>6 P.f.</td>
<td>-</td>
<td>-</td>
<td>1 P.v.</td>
<td>-</td>
<td></td>
<td>Different nationalities with frequent travel to tropical Africa</td>
</tr>
<tr>
<td>Adrar</td>
<td>1 P.v.</td>
<td>-</td>
<td>-</td>
<td>2 P.o.</td>
<td>-</td>
<td>-</td>
<td>Algerian</td>
</tr>
<tr>
<td></td>
<td>1 P.m.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Nigerians</td>
</tr>
<tr>
<td>Oran</td>
<td>Maintenance</td>
<td>2 P.m.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Algerians</td>
</tr>
<tr>
<td>Guelma</td>
<td>1P.f.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>National of Guinea</td>
</tr>
<tr>
<td></td>
<td>1P.v.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>Algerian (see explanation below)*</td>
</tr>
</tbody>
</table>
Table 22. Malaria cases recorded in Algeria during 1987 and the first quarter of 1988 (contd.)

<table>
<thead>
<tr>
<th>Wilaya &amp; date</th>
<th>Phase</th>
<th>Indigenous</th>
<th>Cases and parasite</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cases</td>
<td>parasite</td>
</tr>
<tr>
<td>Djelfa</td>
<td>Maintenance</td>
<td>1 P.f.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Batna</td>
<td>&quot;</td>
<td>1 P.f.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Constantine</td>
<td>&quot;</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6 Wilayat</td>
<td></td>
<td>6</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>IV.Oct-Dec87</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alger</td>
<td>As above</td>
<td>-</td>
<td>-</td>
<td>10 P.f.</td>
</tr>
<tr>
<td>Tamanrasset</td>
<td>Reinforced control</td>
<td>-</td>
<td>-</td>
<td>4 P.f.</td>
</tr>
<tr>
<td>(South)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adrar</td>
<td>&quot;</td>
<td>-</td>
<td>-</td>
<td>3 P.f.</td>
</tr>
<tr>
<td>Oran</td>
<td>maintenance</td>
<td>-</td>
<td>-</td>
<td>1 P.f.</td>
</tr>
<tr>
<td>Blida</td>
<td>&quot;</td>
<td>-</td>
<td>-</td>
<td>1 P.f.</td>
</tr>
<tr>
<td>Constantine</td>
<td>&quot;</td>
<td>-</td>
<td>-</td>
<td>1 P.f.</td>
</tr>
<tr>
<td>Jijel</td>
<td>&quot;</td>
<td>1 P.v.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skikda</td>
<td>maintenance/</td>
<td>1 P.v.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>consolidation</td>
<td>control(south)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ouargla</td>
<td>&quot;</td>
<td>1 P.v.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9 Wilayat</td>
<td>total</td>
<td>3</td>
<td>-</td>
<td>23</td>
</tr>
<tr>
<td>TOTAL 1987</td>
<td></td>
<td>10</td>
<td>-</td>
<td>52</td>
</tr>
</tbody>
</table>
Table 22. Malaria cases recorded in Algeria during 1987 and the first quarter of 1988 (contd.)

<table>
<thead>
<tr>
<th>Wilaya &amp; date</th>
<th>Phase</th>
<th>Indigenous</th>
<th>Relapse</th>
<th>Imported</th>
<th>Induced</th>
<th>Unclassified</th>
<th>Remarks</th>
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<td>I. Jan-Mar 88</td>
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<tr>
<td>Boumerdes</td>
<td>maintenance</td>
<td>-</td>
<td>-</td>
<td>1 P.f.</td>
<td>-</td>
<td>-</td>
<td>Algerian-infection in Benin</td>
</tr>
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<tr>
<td></td>
<td>reinforced control(south)</td>
<td>-</td>
<td>-</td>
<td>1 P.f.</td>
<td>-</td>
<td>-</td>
<td>Algerian-infection in Mali</td>
</tr>
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<td></td>
</tr>
<tr>
<td>Tamanrasset</td>
<td>&quot;</td>
<td>-</td>
<td>-</td>
<td>4 P.f.</td>
<td>-</td>
<td>-</td>
<td>One Algerian, one Tunisian &amp; 2 Africans-infection in tropical Africa</td>
</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Adrar</td>
<td>&quot;</td>
<td>-</td>
<td>-</td>
<td>3 P.f.</td>
<td>-</td>
<td></td>
<td>One Algerian &amp; 2 Africans-infection in Tropical Africa</td>
</tr>
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</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td>2 P.v.</td>
<td>-</td>
<td></td>
<td>One Algerian &amp; one African-infection in Tropical Africa</td>
</tr>
<tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Wilayat</td>
<td>Total</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
and central zones, while *sergentii* appeared to be the principal vector in the south, but the role of *multicolor* could not be ascertained. Upon termination of the pre-eradication survey, the plan of operations was signed in 1966 and the malaria eradication programme was started at the beginning of 1967 in a pilot zone covering certain parts of Sousse and Kairouan governorates with 600,000 inhabitants. DDT house spraying was the principal measure of attack. Subsequently, the programme was extended to other parts of the country passing through the classical phases of the eradication programme. By 1972, the programme covered 10 governorates in the north and centre reaching the consolidation phase. In the south (Gafsa, Gabès and Medenine), the activities were limited to PCD and radical treatment as well as epidemiological studies and control measures in foci of transmission until 1972 when it became possible to advance the programme in this zone in what was considered a pre-consolidation phase.

From 1970 onwards, the annual parasite incidence (API) in Tunisia fell to less than 0.1/1000 population, and to check the malaria situation a parasitological/seroepidemiological longitudinal study was conducted during 1970-1972 as reported on by Ambroise-Thomas et al. (1976). A total of 18 localities was selected in eight governorates grouped in four principal regions A, B, C and D as shown in Fig. 8. For comparing the results, the same sampling procedures were utilized in all investigations conducted every six months: in April and in September/October, (i.e., during the period of the maximum incidence of relapses or new cases respectively) in each of 1970, 1971 and 1972.

Fig. 8. The distribution of 18 localities studied parasitologically/sero-epidemiologically grouped in 4 areas (A-D). The hyphenated line demarcates the northern and southern governorates of Tunisia.

1. Reproduced by permission of Professor P. Ambroise-Thomas from the paper of Ambroise-Thomas et al. (1976) in the *Bulletin of the World Health Organization*. 
As summarized by the authors, a total of 13,044 persons in the 18 selected localities were examined parasitologically for the presence of malaria parasites in the peripheral blood, and serologically for the presence of malaria antibodies by the fluorescent antibody technique using the heterologous *Plasmodium cynomolgi bastianelli* antigen. Six surveys were conducted at 6-monthly intervals. While parasitological examinations yielded only one *P. vivax* infection (1/2171 in the 1st examination and all 10,873 slides in the 2nd examination were negative), the initial seropositivity rate at a titre level of ≥20 was 18.7% and 8.8% at a titre level of ≥40, with generally higher seropositivity in the eastern maritime and southern regions. There was a clear age gradient, showing higher seropositivity, qualitatively and quantitatively, in the older age-groups. The seropositives detected in the first survey was followed up, the re-examination rates varying between 68.5% and 75.4% per survey with 166 persons (40.9%) participating in all six surveys. The serological results indicated residual malaria transmission in one locality in the summer of 1970. In the other localities seropositivity (≥40) declined from the first survey onwards, showing a regression rate that is very similar to that of the natural regression of malaria infections after interruption of transmission. When a discriminative titre level of ≥20 was used, nonspecific titre rises were seen, usually in the summer seasons and normally confined to the lowest titre (1/20). The serological results were evaluated and related to the past and the present epidemiological situation in Tunisia. The serological pattern corresponded to that of disappearing malaria in the absence of new infections. In this first seroepidemiological longitudinal study under conditions of disappearing malaria it has been shown that the serological techniques are suitable for complementing epidemiological assessment and would be particularly valuable in antimalaria programmes once the parasite rate has dropped below the level at which classical evaluation through mass surveys in indicator areas becomes meaningful.

Chadli, Kennou & Kooli (1985) and in more detail (1986) presented a review of the efforts made for the control of malaria in Tunisia since 1903 culminating in a successful malaria eradication campaign from 1966 to 1972, with emphasis on the malaria situation in recent years. The malaria eradication campaign achieved its objectives since the last focus was located in Jendouba, where 16 cases of *P. vivax* were detected in 1975 and six cases in 1976. The last indigenous case was declared in 1979 in the same town. Since 1985, no more foci of active malaria transmission have been observed in Tunisia. However, the surveillance activities still continue with case detection covering the human population in all territories of the country. In this respect, the Pasteur Institute of Tunisia receives annually between 30,000 and 40,000 blood slides for microscopical examination which represent about 20% of the total slides collected from different governorates. For vector control, the potential breeding places are constantly inspected and treated when found positive for vector larvae. The number of malaria cases detected annually from 1973 to 1985 were presented graphically as shown in Fig. 91.

1. Reproduced by permission of Prof. A. Chadli and the Pasteur Institute, from the paper of Chadli, Kennou & Kooli (1986) in *Arch. Inst. Pasteur, Tunis.*
During 1978-1985, 68 imported malaria cases were diagnosed, of whom 85% were persons who resided in Africa, 7% in Arab countries and 7% in Asia. Classification of these imported cases by profession showed that 34% were Tunisians working abroad, 27% students, 17% diplomats, 7% foreign technicians, 14% marine personnel and 7% others. A new problem has been posed in Tunisia which is transfusional malaria. In 1985, three cases were recorded as follows:

- a case of *P. falciparum* in a woman who had a high fever after her return from France where she had undergone surgical intervention;

- two cases of *P. malariae* in patients who received blood transfusions from Tunisian blood donors. The infection of these donors was identified by IFA tests.
The diagnosis of transfusional malaria is often difficult because postoperative fevers are usually attributed to bacterial origin. On the other hand, systematic detection of infection in donors by the classical technique is confronted with the difficulty of the presence of the malaria parasites at submicroscopic levels.

The authors concluded that with continuous efforts and the availability of manpower and material, malaria transmission could be brought to an end. Surveillance should be pursued and the specialized service of malaria should be integrated in the general health services. This process of integration is not yet complete, since for example, the malaria microscopists are still working for their own field while they should be made polyvalent. It is suggested that this integration should proceed progressively taking into consideration the epidemiological situation and the health infrastructure of each region. Surveillance should be extended to cover travellers coming from endemic areas.

As mentioned in the INTRODUCTION, Farid (1987) in an unpublished document to WHO presented malaria profiles for each country of the WHO East Mediterranean Region. The country malaria profile of Tunisia was shown as follows:

- **Population**: 7.5 million
- **1984**
  - No. slides examined: 165,763
  - No. positive slides: 5
  - No. falciparum cases: 4
- **1985**
  - No. slides examined: 168,047
  - No. positive slides: 21
  - No. falciparum cases: 9
- **1986**
  - Not available
- **P. falciparum** resistance to chloroquine: nil

Vector of malaria according to vectorial importance - information on insecticide resistance:
- **An. labranchiae** - DDT
- **An. sergentii** (south)
- **An. multicolor** (south - on epidemiological evidence)

Main vector control measures: Directed towards mosquito nuisance and other vectors mainly through ULV application.
- Case detection: PCD
- Development of PHC at peripheral level: Good
- Development of PHC at referral level: Good
- Malaria control: integrated with other parasitic diseases control programmes.
- Malaria training centres: not available
- Trained manpower: Available but not sufficient
- Special problems: imported malaria

In Libya, according to Goodwin & Paltrinieri (1959), a malaria control programme was conducted during 1954-1957 in certain malarious oases of Fezzan province (see map of Libya Fig. 3 above). No malaria statistical data were available before this programme, but it was assumed that control by house spraying reduced the incidence of malaria in those oases that were covered by this programme. Subsequently, a pre-eradication survey was conducted during 1957-1958. P. falciparum and P. vivax were the only parasite species encountered occurring at a ratio of 3:1. The malaria incidence was not high and epidemics had been rare in the past. Many of the farmers abandoned their farms and migrated to Tripolitania. When farms were abandoned, the dug wells and other sources of irrigation water were also abandoned. It was expected that this would increase breeding places suitable for anopheline vectors, and consequently the malaria incidence would increase. At the time of the pre-eradication survey, malaria was classified on the whole as hypoendemic in Fezzan oases.

As shown under 2.5 and 4.5 above, the vectors in Fezzan are sergentii and multicolor, the latter was incriminated only on epidemiological grounds.

In a review of the history of malaria in Libya, Gebreel (1982) noted that based on the pre-eradication survey, malaria occurred in each of the three regions or governorates of Libya: in 25 villages in Fezzan, 4 villages in Tripolitania and 2 villages in Cyrenaica. In 1960 a malaria eradication programme was launched aiming at the following:

1. Supplementary information has been added by the writer in some country profiles.
(a) To achieve complete eradication of malaria in the whole country by applying appropriate measures:
- residual house spraying, antilarval measures and chemotherapy;
- epidemiological surveillance in order to ensure total case detection and treatment.

(b) To promote training national personnel of various categories in malaria eradication techniques.

(c) To develop within the national health service a mechanism for active vigilance against the reintroduction of malaria following its eradication.

As a report on the malaria situation Libya by Kadiki & Ashraf (1972) is not available, an abstract of this report in the Tropical Disease Bulletin (TDB) 1974, 71(8) Abst. 1688, pp. 787-788 is reproduced here¹. The abstract was made by Prof. L.J. Bruce-Chwatt who also commented on the report as shown below:


"This is a useful review of the past and present malaria situation in Libya. It comprises a description of the country, the previous history of malaria, the progress of the eradication programme and its future prospects. Out of the total population of over 2 million (in 1971) about 150 000 live in malarious areas, mainly in the Fezzan, but also in northern and eastern Tripolitania and in eastern Cyrenaica. In the 1950s, malaria surveys showed a parasite rate of the order of 3%. The main vectors were Anopheles sergentii and A. multicolor. Malaria eradication by DDT spraying started in 1959, and in 1963 the overall annual parasite incidence fell to 0.3%, but during the following two years, because of the considerable amount of imported and introduced malaria, the index rose to 2.1%. Since 1966, subsequent to renewed antimalarial activities, the number of cases of malaria decreased steadily; during the period 1969-1972 only 3 indigenous cases of malaria were detected, while 39 cases were imported from various parts of the world. A further 21 cases, so far unclassified, were reported in the eastern region in 1972. A strict vigilance system has been organized to prevent the importation of malaria. In 1972, the western and eastern regions (Tripolitania and Cyrenaica) were in the maintenance phase of malaria eradication while the southern region (Fezzan) was in the consolidation phase.

This is a valuable report although marred by many typing errors. The taxonomic synonymy of A. mauritanicus and A. coustani has not been indicated. The mention of a finding (in 1953) of a few specimens of A. gambiae at Edri and Ubari in the Fezzan, north of the 27° N parallel is of considerable interest."

It seems that the date of finding An. gambiae s.l. was a misprint as it should read 1935.

However, the finding of An. gambiae s.l. has not been supported by further surveys (Shalaby, 1972 and Ramsdale, 1989 – in press). The only reference cited by the last two authors was that of Lodato (1935) who recorded An. gambiae s.l. at Edri in El-Chati area and Ubari in Wadi El-Adjal in Fezzan province. Ramsdale (loc.cit.) doubts the validity of this record and thinks that it might have been due to misidentification.

Gilles (1982) advised on protection from malaria imported into Libya, since a high level of malaria control has been achieved and autochthonous cases have become rare. Receptive areas where transmission could recur if imported cases are introduced, pose a great danger. The biggest threat for the reintroduction of malaria in Libya comes from the large number of migrant labour groups originating from malarious areas, illegal migration from contiguous malarious countries, and to a lesser extent from Libyans who visit malarious countries for various reasons, and have been inadequately protected. The following prophylactic measures were advocated:

(a) Libyan nationals: All nationals visiting malarious areas should take prophylactic drugs one week before departure, throughout their stay and for four weeks after their

¹ Reproduced by permission of Dr Carolyn Brown (ed.), Tropical Disease Bulletin and Prof. L.J. Bruce-Chwatt.
return. Chloroquine 300 mg weekly is satisfactory except for chloroquine resistant P. falciparum areas. If visiting these areas Maloprim (pyrimethamine + dapsone), 1 tablet weekly instead of chloroquine should be prescribed.

(b) Migrant labourers: All migrant labourers on registration and/or arrival in a receptive area in Libya should be given presumptive treatment for malaria as follows:

Day 1: chloroquine 600 mg (single oral dose: 150 mg base x 4).
Day 2: primaquine 30 mg (single oral dose: 7.5 mg x 4).

If they develop a fever and are found positive for malaria, they should be given radical treatment.

(c) Illegal migrants: This group is difficult to identify and manage. If they develop fever and are found positive they should be given radical treatment.

Gebreel, Gilles & Prescott (1985) reported on a seroepidemiological study for malaria in Libya. In the past 10 years, considerable socio-economic development in Libya has created favourable conditions for the possible recrudescence of malaria transmission. There has been an extension of water bodies of all types arising from agricultural and housing developments, coupled with a heavy influx of immigrant labourers from many parts of the world including malarious countries, with many persons having asymptomatic parasitaemia or potentially relapsing infections. In 1978, health screening of 16 207 immigrants and inhabitants in Sebha, the principal town of Fezzan province revealed the presence of 46 positive slides: 44 P. vivax and 2 P. falciparum. Of these, 28 were foreign immigrants mainly from India, Pakistan and tropical Africa, the remaining were Libyan nationals. All foreign cases were P. vivax except one P. falciparum from Pakistan. In September-October 1980 a small outbreak of malaria, involving 18 persons, occurred in Zuara, a coastal town surrounded by marshland, approximately 120 km west of Tripoli and 70 km east of the Tunisian border. On 5 September two Tunisian immigrant workers were found positive for P. vivax; during the following 36 days a further 16 cases of P. vivax were diagnosed. These comprised 11 Libyan residents, none of whom travelled outside Libya, one Sudanese, one Indian and three more Tunisian immigrants. No vector species could be discovered. However, it was clear that local transmission had taken place within a receptive area. This outbreak suggested that, although malaria transmission was uncommon in Libya, there is a risk of recrudescence, and possibly the reintroduction of malaria arising directly from the large numbers of immigrants currently arriving in the country for periods varying from six months to one year. To assess this risk, a seroepidemiological investigation was carried out during August-September 1981 using IFA test with blood specimens collected by the fingerprick, filter paper method. The specimens were taken from 330 immigrant workers, none of whom had resided in Libya for more than six months, and 106 native schoolboys, none of whom had ever left Libya nor even their birthplace. Sampling covered the following localities as shown in Fig. 10.1.

- Zuara: 100 adult labourers, all from India, employed on port and sewage treatment construction sites; the locality was the site of the 1980 outbreak.

- Ghat: 81 adult labourers, all from India, employed on a hospital construction site in the locality which is a small town in Fezzan, adjacent to the Algerian border, approximately 1000 km southwest of Tripoli.

- Derna: 140 adult immigrants from non-Asian origin (Algeria, Bulgaria, Gambia, Niger, Tunisia and European Turkey). They were employed in various types of work related to urban building construction. Derna is a coastal town about 300 km east of Benghazi.

- Ghat: 106 native schoolboys, 6-10 years old.

For primary screening P. fieldi antigen was utilized as a detector of unspecified malarial infection in the examined sera, tested at a dilution of 1:16. Thus, all non-reacting sera were classed as malaria-negative, indicating a lack of exposure to malaria of any type. All primary screen reactors were further tested at 1:64 dilutions against both P. fieldi and P. falciparum antigens, any of those reacting strongly at 1:256

Fig. 10. Areas of seroepidemiological studies in Libya.

was further tested at dilutions of 1:1024 and 1:4096 against the relevant antigen. Those sera reacting strongly to \textit{P. falciparum} and less strongly to \textit{P. fieldi} were classed as falciparum positive. Conversely, those reacting more strongly to \textit{P. fieldi} were classed as non-falciparum positive. It would be possible to define the individual nature of these latter infections by use of species-specific antigen, but in this context it is necessary only to distinguish between \textit{P. falciparum} as a dangerous parasite, and other species which are less directly dangerous but more menacing from an epidemiological standpoint since their human carriers may relapse and initiate transmission. Roughly half of the immigrants from India, 47% and 46.9% from Zuara and Ghat respectively, yielded IFA positivity in the primary screening, whilst those from a variety of other origins outside Libya, yielded a ratio of only 10.7%. Those sera reacting at a titre of 1:64 or greater were considered as indicating recent and/or heavy infections, even, possibly asymptomatic parasitaemia. The native schoolboys acted as a control group having been born after the malaria eradication campaign of the 1960's, and not having travelled outside Libya, nor even very far from Ghat; they were all 100% negative. In all immigrant groups, there appeared to be a rate of \textit{P. falciparum} positive at 1:64 or greater averaging 2.8%. Indian immigrants presented a positivity rate of strong reactions at 1:64 or greater ranging from 12.4% to 19% in respect of species other than \textit{P. falciparum}. This rate constitutes the potential relapse rate. Immigrants originating from countries other than India yielded a positivity rate of 3.4%, at > 1:64, to non-falciparum or potentially relapsing species. Thus, all short-term immigrants from unspecified malarious areas may be considered to present a risk of introducing either relapsing or non-relapsing malaria to Libya of the order of 3%. Indian immigrants, in particular, present a risk to the Libyan community of relapsing malaria, principally \textit{P. vivax}, as high as 19%. Furthermore, the native community at risk, particularly the schoolchildren, would appear to have little or no immunity to malaria as a result of the previous effective eradication campaign.
To conclude, the authors considered that a high degree of control of malaria transmission has been achieved in Libya, to the extent that autochthonous cases had become uncommon until 1980 when an outbreak occurred in Zuara, in coastal Tripolitania. The outbreak indicated the possible danger of the resurgence and establishment of malaria transmission as has occurred in several countries in different parts of the world, following earlier effective control. There are many receptive areas in Libya where transmission might occur if active human infection were introduced. The principal threat comes from large groups of immigrant workers originating from distant malarious areas, and to a lesser extent from neighbouring countries, as well as inadequately protected Libyans who spend periods in malarious areas abroad. The present investigation demonstrated that nearly half of immigrant workers from India probably had been exposed to malaria infection and that as many as 1% have antibody levels suggesting recent and/or heavy infection; a majority of these persons have been exposed to relapsing types of Plasmodium infection. While it would appear that immigrants from other geographical areas present a lesser threat in terms of the numbers of potentially relapsing infections, it is clear that the immigrant labour force from malarious countries on the whole present a risk to the community particularly in area such as Ghat, where the entire population of schoolchildren may be non-immune. It may be assumed that vector populations will have recovered from the impact of the previous spraying campaign, and that modern development would assist in extension of breeding places of vector populations. In addition to sergentii and multicolor in Fezzan, labranchiae could prove to be a particular threat in coastal Tripolitania marshland. Thus, a thorough anopheline survey is needed to determine the current distribution and density of the main vectors. Moreover, an expanded immigrant and resident antibody survey similar to that of the present study would assist the formulation of malaria control policy in future.

In his recent review of anophelines and imported malaria in Libya, Ramsdale (1989 - in press) recalled that Fezzan province has a long history of epidemic malaria, with many outbreaks of P. falciparum brought by carriers transported by caravans coming from the south and transmitted by local vectors (citing Gebreel, unpublished). P. vivax used to be most prevalent near the coast. At the present time, most imported malaria is of P. vivax infection, though there are some cases of P. falciparum. Moreover, most parasite carriers quickly disperse from the ports of entry, now mainly airports, making all parts of the country equally vulnerable. The desert species sergentii and multicolor considered to be the main vectors of malaria are sufficiently prevalent to maintain malaria transmission in most of Libya. Although direct proof is lacking, epidemiological evidence points to the vectorial role of multicolor, and this species is able to maintain a low level of malaria transmission over a long period. In contrast to Maghreb where labranchiae is the principal vector and is still responsible for residual foci of P. vivax, this species in Libya is important only in a very restricted area. Almost all records of this species and other marsh breeding mosquitoes are found in a circumscribed coastal area around Touarga in Tripolitania.

In the unpublished document of Farid (1987), the country malaria profile of Libya was shown as follows:

- Population: about 3 million \(^1\)
- Population at risk: nil
- No. slides examined: 1984 1985 1986
  - No. positive slides: 7 024 5 862 not available
  - No. falciparum cases: 117 71 2
  - P. falciparum resistance to chloroquine: nil
- Vectors of malaria according to vectorial importance - information on insecticide resistance:
  - An. sergentii, An. multicolor (the latter considered vector on epidemiological evidence)
  - An. labranchiae (in a very restricted area in Tripolitania). For resistance, see below.
- Main vector control measures: DDT house spraying in foci of transmission; temephos larviciding.
- Case detection: Mainly through PHC
- Development of PHC at periferal level: Good
- Development of PHC at referral level: Good

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\(^1\) This figure was revised later (see below).
From recent information communicated to WHO/IAP, the malaria situation in Libya in 1987 show the following:

(population given as a mid-year estimate in 1000s).

- Total population: 4 000
- Population of originally malarious areas: 1 400
- Population protected by house spraying: 100
- Population protected by other anti-vector measures: 100
- Population under surveillance: 4 000
- No. slides examined: 4 699
- No. positive slides: 75 (64 P. vivax & 11 P. falciparum) - all imported from abroad.

The epidemiological situation remained satisfactory in 1987, as no autochthonous cases have been detected, and only imported cases were recorded (from tropical Africa, India and Turkey), compared with 57 in 1986 (54 P. vivax & 11 P. falciparum. The vectors remained susceptible to DDT.

In Egypt, it has been shown above (see under 3.5) that pharoensis is the main vector of malaria in the Delta and Nile Valley. It is joined by sergentii as an additional vector in Faiyum governorate, while sergentii acts as the main vector in the oases of the western desert. An. gambiae s.l. probably An. arabiensis, (the species which has been identified from Sudan), invaded Upper Egypt in 1942 until it was exterminated in 1945 through an intensive campaign during 1942-1945 as shown below.

Halawani & Shawarby (1957) reviewed the history of malaria in Egypt from the time of the ancient Egyptians until 1956 including the gambiae-eradication campaign. The parasite species recorded during 1940-1953 were P. vivax, P. falciparum and P. malariae at a ratio of 13:18:1. The last parasite species had a limited distribution, being found in Siwa and Bahariya oases as well as Faiyum governorate, though a few cases were also reported from the Suez Canal zone and the eastern part of the Delta. P. ovale was recorded only on three occasions, but two of these were of doubtful local origin. The available data on malaria incidence during 1940-1953 were not malarionetrical standardized, hence not always comparable. Nevertheless, the data could indicate that Lower Egypt has always been more malarious than Upper Egypt, except for the epidemic caused by the invasion of gambiae s.l. into Upper Egypt (1942-1945). The data also showed that malaria has been slowly regressing during the previous 40 years, a great drop in incidence was particularly noted since 1950. Examination of blood slides collected from all age-groups during 1940 showed parasite rates of 6.3% and 3.6% in Lower and Upper Egypt respectively. In 1953, the parasite rates dropped to 0.2% and 0.04% respectively. Also, data of infants below one year of age reporting to hospitals showed that while in 1940 the morbidity rates were 19.9% and 6.3% in Lower and Upper Egypt respectively, the rates declined in 1953 to 0.4% and 0.08% respectively. The improvement noted was most probably the outcome of continuous malaria control measures applied, whether these were premanent such as drainage and control of irrigation waters, or temporary involving the use of insecticides. The authors, however, thought that if for one reason or another the present situation is disturbed, malaria might revert to its former endemic level. For this reason, they advocated that the best policy would be to plan for complete eradication of the disease by applying intensive measures of control in those localities where malaria transmission exists, while maintaining surveillance simultaneously in localities where no transmission seemed to have existed.

The authors further described in detail special campaigns for the control of malaria in the oases of the western desert and Faiyum governorate. Gaining from the successful experience of the gambiae-eradication campaign, efforts were directed to eradicate sergentii from Dakhla and Kharga oases. According to an unpublished report by Madwar & Shawarby (1950), the mean parasite rate in the two oases was 11.7% with P. vivax and P. falciparum occurring at a ratio of 1.2:1. The rate in Dakhla was about 3 times as high as those of Kharga. An intensive larviciding campaign aimed at eradication of sergentii was conducted during 1946-1947 with a long-term follow up. The larvicide used was 5% DDT in fuel oil instead of Paris green which proved successful in the gambiae-eradication
campaign. No sergentii could be found for two years after the discontinuation of the larvicidal measures, despite active searches during the breeding season, although other anophelines were still present. After 1953, the malaria incidence declined drastically from an initial 15% in Dakhla and 6% in Kharga to practically nil. However, a slight rise in malaria incidence was observed later in Dakhla, together with the reappearance of sergentii which probably was reintroduced from Bahariya oasis, and gradually spread from the point of reappearance. Residual house spraying carried out in 1951 successfully reduced again the malaria incidence.

This experience with sergentii in the oases supports the view that the success achieved with the extermination of an exotic species such as An. gambiae s.l. should not be expected to materialize with the eradication of an indigenous species.

In the Siwa oasis, a malaria control campaign was conducted by applying DDT house spraying instead of larviciding. Also here sergentii was the main vector which existed together with multicolor at a ratio of 2:1. From a blood survey carried out in December 1949, the mean parasite rate was 18.8% with P. falciparum and P. malariae existing at a ratio of 2:1; no P. vivax was found in that survey. The infant parasite rate recorded in 1950 was 25%. DDT was applied in four rounds in 1951, two rounds in each of 1952 and 1953, and one round only in 1954. The parasite rate fell dramatically, with the P. falciparum rate decreasing from 14.4% to 0.18%, and the P. malariae rate from 5.2% to 1.1%, while the infant parasite rate was zero. By 1955, malaria had practically disappeared as no cases could be found, while in 1956 only three P. malariae cases were encountered in a small village. The entire population of this village (150 inhabitants) was treated and surveillance maintained. The vector, sergentii, though reduced in numbers, was still present. The cost of this campaign was much less than larviciding. In the Bahariya oasis, examination of 8841 blood slides collected from all age-groups during April and December 1954 showed a mean parasite rate of 6.3% with P. malariae being predominant. The incidence of the parasite species was P. malariae 3.4%, P. falciparum 2.1%, and P. vivax 0.2%. P. malariae was present in all months from April to December 1954 with a peak in September; P. falciparum was encountered at a very low level until October reaching its highest level in November-December. P. vivax which was practically absent during the year, was encountered mainly during October-November, but at a very low level. As in the other oases sergentii was the main vector, with multicolor and pharoensis being present. The principal control measure was the administration of the antimalarial drugs hitherto available to the entire population of the oasis, but leaving two villages untreated for comparison. The drug used was camoquine/primaquine (one tablet containing 0.15 g camoquine + 0.01g primaquine). During January-March 1955, the population was treated at fortnightly intervals, giving three tablets in a single dose to the age-groups above 8 years, and reducing the dose for younger age-groups. The parasite rate as measured from examination of 514 blood slides fell from 9.7% to 1.7%. The same regimen and schedule was administered during the peak season, September-October, also reduced the parasite rate to 0.9% after it had risen to 4%. In the untreated village the parasite rate was much higher (8.6%). In Falyum governorate, DDT house spraying was applied starting from 1947, but due to many difficulties including shortage of the insecticide and transport, and withdrawal of personnel to deal with the cholera epidemic in 1947 and the reappearance of An. gambiae s.l., the spraying coverage was inadequate. Nevertheless, the results were encouraging, as the number of malaria cases reported fell gradually from 3 069 in 1947 to 49 in 1952. From 1952 to 1954, the number of notified cases fell further to 11. When the spraying campaign was discontinued in 1955, the number of cases rose to 101.

Following the detection of dieldrin/HCH resistance and subsequently DDT resistance in pharoensis during the early 1960's, field trials were conducted to assess the operational implications of these resistances and to evaluate alternative insecticides and methods of application. The first trial was conducted in Giza governorate in the rural outskirts of Cairo covering a population of 28 000 inhabitants living in four medium-sized villages and about 60 scattered hamlets. The trial was reported on by Zahar et al. (1966) (see under 3.10 above). The site of the trial was regarded as the field training area (F.T.A.) of the former WHO Regional Malaria Eradication Training Centre. Prior to 1960 no house spraying had been carried out in this area. Pest control was mainly directed against the cotton leaf-worm, using HCH/DDT dust until 1957-1958. In 1961, a heavy infestation of cotton-leaf worm dictated the use of large quantities of these and other insecticides including organophosphate and carbamate compounds. The use of insecticides in agriculture seemed to have exerted selection pressure on pharoensis resulting in the appearance of
organochlorine resistance initially. Base-line parasitological and entomological data were collected from the F.T.A. during 1959-1960. *P. vivax* was the only infection encountered in this area, with an overall parasite rate of 11.67% in 1959 (2150 blood slides examined from all age-groups). From the end of June 1960 to 1962, the houses of the area received one round of DDT spraying annually at a dosage of 2 g/m², and parasitological/entomological evaluation was pursued. Entomological observations were maintained in an unsprayed area, Marg, on the southeastern side of the Delta. Conditions in this area were generally similar to those of the F.T.A., though with much rice cultivation and a greater natural output of *pharoensis*. In 1961, however, rice cultivation was restricted in the Marg area and the density of *pharoensis* dropped to a relatively low level, and in 1962 rice cultivation was much more restricted, hence the density of *pharoensis* was too small to allow comparison with the sprayed area. Due to limitation of staff, parasitological studies could not be conducted in the Marg unsprayed area. As summarized by Zahar (1974), under the influence of DDT spraying the overall parasite rate dropped in 1960 to 20% of its original prespraying level of 1959. This indicated an adequate regression during the first year of attack, which, if maintained, would ultimately have resulted in diminution of malaria to a very low level (Macdonald & Gockel, 1964). There was evidence that the insecticide was wearing off in September 1960, when four infants born after spraying became positive. Except for this temporary reversal, reflecting also operational defects, the overall picture of 1960 was generally satisfactory. The control of vector longevity was satisfactory when the average trap mortality was 70% or more; it became unsatisfactory when the average was below 54%, (see Table 17 above). In terms of probability of survival through one day (p), results were adequate as 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 survival through the sporogonic cycle might be approximately 0.002. In 1961, the second year of DDT spraying, the crude parasite rate showed a much smaller decline, indicating a less favourable response. It fell only from 2.37% to 1.87%, the latter being equal to 16% of the base-line level, instead of the 4% that would have been expected after two years of attack had the initial rate of decrease been maintained. Trap mortality was only slightly over half the 70% level required for satisfactory control (37.6%, 10-17 weeks postspraying). Vector probability of daily survival (p) increased to 0.62 and through the sporogonic cycle to 0.013, i.e., over six times the critical value of 0.002 suggested on the basis of the data of satisfactory response. In 1962, the third year of attack, the general parasite rate fell to 4.5% of the original 1959 level, compared with the expected level of 0.4% had satisfactory control been continuously maintained. That rate of decline implied further low-grade transmission in the sprayed area in the third year of attack. The critical levels for the probability of daily survival and through the sporogonic cycle were exceeded. The trap mortality was only 41.8%, again much inferior to the 70% required for satisfactory control. This unsatisfactory control coincided with a deterioration in the susceptibility level of *pharoensis* to DDT, which was determined periodically throughout the trial.

Further observations by Shawarby et al. (1965) confirmed the ineffectiveness of DDT spraying even when applied in two rounds, each at 2 g/m², in the same trial area in 1963. However, it was not certain whether DDT resistance was the main factor responsible for continued transmission, or if outdoor biting and outdoor resting of the vector population had played a role.

Three insecticidal trials were conducted in Kafr El Sheikh governorate in the northern part of the Delta during 1965 as reported on by Shawarby et al. (1967a, b & c). The sites of the trials had extensive rice cultivation with a high *pharoensis* output. Three trial areas were selected: one for DDT with a population of 37 785 inhabitants, a second for malathion with a population of 57 132 inhabitants, and a third for HCH with a population of 48 842 inhabitants. A fourth area with 45 846 inhabitants was left unsprayed to serve as a check area. In 1964, pre-operational base-line parasitological surveys in the four areas showed the following:

- **DDT area**: pre-season (May), 2 cases/1000; post-season (October), 36/1000, of which four were *P. falciparum*.

- **Malathion**: 1-4/1000 in May (5 *P. vivax* + 2 *P. falciparum)/5128 persons examined; 5.0/1000 in July; 2/1000 in October. All cases in the last two surveys were *P. vivax*.

- **HCH**: 1.6/1000 in March; 7/1000 in July-August (18 *P. vivax* + 3 *P. falciparum)/2961 persons examined; 3.8/1000 in October (7 *P. vivax* + 4 *P. falciparum)/2906 persons examined)
The trials were assessed parasitologically and entomologically using different techniques. The results are summarized as follows:

- DDT applied in one round during 16 May–6 June 1965 at a calculated dose of 2.9 g/m² gave moderate impact on vector population up to the 13 weeks as assessed entomologically, while the parasitological data indicated resumption of malaria transmission after the 8th week post-spraying. Marked deterioration of the susceptibility of pharoensis to DDT occurred, as one hour exposure to 4% DDT gave only 1.47% mortality in September towards the end of the season, as compared with 35% mortality at the beginning of the season.

- Malathion applied in one round during 15–26 May 1965 at a calculated dose of 1.1 g/m² remained effective for 9 weeks post-spraying, although trap mortality continued to be high for a longer period, as assessed entomologically. However, parasitological evaluation indicated that malaria transmission was resumed after the 7th week post-spraying.

- HCH applied in one round during 22–30 May 1965 at a calculated dose of 0.44 g HCH/m² produced moderate effectiveness up to the 7th week post-spraying, as assessed parasitologically/entomologically, after which period malaria transmission resumed.

A fourth trial was further conducted also in Kafr El Sheikh governorate in the same area of HCH trial as reported on by Shawarby et al. (1968). The aim was to investigate whether continued spraying with HCH on a longer term would overcome the double DDT/dieldrin resistance in pharoensis. Thus, HCH in the form of lindane was sprayed in two rounds at 0.4 g/m² each: the first in June 1966, and the second in August of the same year. In 1967, only one round was applied in July. Entomologically, although there was some reduction in the parous rate and the man-biting rates in the sprayed area, the population of pharoensis tended to recover during September–October. However, massive application of pesticides for crop protection might have had an impact on the vector population as evidenced by marked reduction in the parous rate in the unsprayed check area during July–August in 1966 and 1967. Parasitological evaluation failed to provide evidence, since malaria seemed to have been declining to a very low level in the whole area. In 1966, only two P. vivax cases were detected among 17 593 blood slides examined from the sprayed area. In 1967, not a single positive could be found among 1886 slides collected from the sprayed area, and 1 648 slides from the check area, although all were sampled from fever cases by active case detection.

[These trials showed that none of the hitherto available insecticides gave satisfactory control of malaria transmission due to organochlorine resistance in pharoensis or a short period of effectiveness of malathion applied at a lower dosage].

As remarked by Zahar et al. (1966), malaria incidence showed a declining trend in the early 1960's; the number of cases reported in the whole country dropped from 95 933 in 1959 to 83 221 in 1960, 53 160 in 1961, and 45 875 in 1962. This was explained as possibly being due to a natural recession of malaria, and also to the wide-scale distribution of antimalaria drugs as well as the use of a variety of pesticides in agricultural pest control.

In the early 1960's, Egypt preferred not to establish a malaria eradication programme, but opted to continue malaria control activities on a long-term with the ultimate aim being malaria eradication. In an unpublished report to WHO, Rakha (1984) reviewed the history of malaria control in Egypt and described the control activities undertaken by the Malaria Control Section of the Ministry of Health. The malaria parasites are P. vivax and P. falciparum with the latter being confined to Faiyum governorate. P. malariae which used to exist in the past has been eradicated from the oases and is no longer found in Egypt. The number of malaria cases detected in the whole country after having been reduced to 1900 (0.27% of slides examined) in 1969 increased again to 4881 (0.73%), 20 783 (1.8%), 23 190 (1.72%) and 21 198 (1.52%) in 1970, 1971, 1972 and 1973 respectively. Subsequently, the number of cases steadily declined reaching 423 (0.03%) of 1 123 727
slides examined) in 1982. The Malaria Control Section continued to expand until it includes at the present 100 malaria units (or stations) and 200 sub-units distributed all over the country. The section is responsible for the technical supervision of the work of the malaria stations. [Administratively, the malaria stations and sub-units are under the responsibility of the provincial health services]. The activities undertaken were outlined by the author as follows:

(a) Surveillance: PCD includes blood examination of all patients attending the malaria stations and from fever cases attending hospitals and rural health units, as well as treatment of all positive cases. ACD is undertaken by house to house visits for collection of blood slides from fever cases and giving presumptive treatment, as well as radical treatment of positive cases as proved by microscopical examination.

(b) General surveys and epidemiological investigations: Parasitological surveys covering 10% of the population are carried out in villages. Epidemiological investigations are carried out in conjunction with positive cases.

(c) Larviciding operations: The area under the responsibility of each malaria station and substation is larvicided weekly using fuel oil mixed with Triton X-100 as a spreading agent.

(d) Spraying operations: Houses in villages with high malaria incidence or in areas with rice cultivation are sprayed with malathion at a dose of 2 g/m².

(e) Anopheline larval and imago surveys: Routine observations are carried out in potential breeding places, and imago collections are made in fixed capture stations as well as other houses selected at random.

[The author did not give any information on imported malaria, although Egypt has a lot of contact with malaria endemic countries].

The country malaria profile of Egypt (Unpublished document by Farid, 1987) was shown as follows:

- Population: about 50 million
- Population at risk: 13 million
- Population of originally malarious areas: 40 000
- Population of areas claimed to be freed from malaria: 29 000
- Population under malaria control programme: 11 000
- Population protected by house spraying: 2 000
- Population protected by other anti-vector measures: 40 000

- Population: about 50 million
- Population at risk: 13 million
- No. slides examined: 1 028 680
- No. positive slides: 194
- No. P. falciparum cases: 10
- P. falciparum resistance to chloroquine: neither reported, nor suspected.
- Vectors of malaria according to vector importance—information on insecticide resistance:
  - An. pharoensis - DDT/dieldrin; OP & carbamates
  - An. sergentii - DDT (localized distribution in Faiyum & oases)
- Main vector control measures: malathion house spraying and temephos larviciding.
- Case detection: ACD & PCD adequately conducted in foci of transmission
- Development of PHC at peripheral level: Good
- Development of PHC at referral level: Acceptable
- Malaria control: is decentralized as part of PHC system and technically guided centrally.
- Malaria training centres: available in Beheira, Tanta, Cairo and Faiyum.
- Trained manpower: sufficient
- Special problems: agricultural practices.

From the information communicated to WHO/MAP, data of the malaria situation in Egypt in 1987 show: (population given as a mid-year estimate in 1000s).

- Total population: 51 000.
- Population of originally malarious areas: 40 000.
- Population of areas claimed to be freed from malaria: 29 000.
- Population under malaria control programme: 11 000.
- Population protected by house spraying: 2 000.
- Population protected by other anti-vector measures: 40 000.
Seroepidemiological surveys were carried out in different governorates in Egypt during 1977-1979 as reported on by Hassan et al. (1983). Antigen slides were prepared in London from schizonts of P. falciparum obtained from an infected blood of Aotus monkey for IFA test. Due to an inadequate number of antigen slides, the number of blood samples for testing had to be limited to 1,471 samples from Faiyum governorate and 723 from Qaliubiya governorate. The samples represented all age-groups, but about 30% of the total was taken from children of school age. In the other governorates of the Delta and the Canal Zone sampling was restricted to 1,000 children of 5-9 years age-group, allocating 200 samples for each governorate: Kafr El Sheikh, Beheira, Gharbiya, Sharqiya and the Canal Zone.

Parasitological examination of 1,471 blood slides collected simultaneously from Faiyum showed an overall parasite rate of 6%, with the rates in children of the age-groups 0-4 years and 5-9 years being 7.8% (90 examined) and 8.5% (524 examined) respectively. None of 736 blood slides collected from all age-groups in Qaliubiya governorate were positive. No blood slides were collected from the other governorates for parasitological examination. Serologically, Faiyum showed the highest positivity rate. Of 524 children of 5-9 years age-group, 46 (8.8%) were seropositive at a titre of 1/64, 34 (6.5%) at 1/256, 20 (3.8%) at 1/1024 and 3 (0.5%) at 1/4096. In Qaliubiya, the age-group of 5-9 years (427 examined) showed a maximum titre of 1/256 with the positivity rate being 1%. This was taken to indicate that the degree of malaria endemicity in Qaliubiya was much less than in Faiyum. In the other governorates, the positivity rates were very low and none of the samples examined from Kafr El Sheikh and Gharbiya recorded the level of specificity, 1/64, and only one was positive at this titre from 114 and 29 samples examined from Beheira and Canal Zone respectively, while in Sharkiya only one of 16 samples examined was positive at 1/256. These results led the authors to deduce that in the Delta region, there were some hidden foci of malaria transmission that could remain undetected. This condition was thought to be due to a combination of factors: irregular mass application of pesticides in agriculture, drug distribution which depresses the parasitaemia to a submicroscopical level, and variation in vector density from year to year. The last factor is thought to be due to alternating crop cultivation, i.e., rotation between rice and cotton cultivation, as well as other crops every two years in the Delta. Since parasitological examination under such conditions would be extremely inadequate, it was suggested that a serological survey once per year covering children of 5-9 year age-group should be conducted, preferably 6-8 weeks after the end of the transmission season in order to give a chance to latent infected persons to produce detectable antibodies. In Faiyum, the follow-up of the old positive persons and the examination of new individuals gave an indication that transmission is perennial in this governorate. To verify this, it was proposed that newly born infants should be examined longitudinally to exclude the possibility of prolonged or delayed incubation period or the occurrence of relapses.

Hassan, Mohamed & El Said (1983) further carried out a serological study in Aswan governorate. This was in conjunction with a case of P. falciparum detected in a locality of the capital, Aswan town. Based on the epidemiological investigation, the case was classified as imported. From the same locality, blood samples were collected from 207 persons of all age-groups, for parasitological examination and for IFA test. Parasitological examination showed that all 207 blood films collected from different age-groups were negative. Serologically, 13 persons were positive: 5 at a titre of 1/16, 7 at 1/64 and 1 at 1/256 (over 40 years of age). In order to satisfy the requirements of a high specificity in this area with a low frequency of antibodies, the discriminating titre of 1/16 was not considered as suggesting recent malaria infection in the population examined. The seven positive cases at the titre of 1/64 and one at 1/256 may suggest recent or concurrent infection. Aswan and the border area with Sudan are being routinely subjected to protective measures to prevent the reintroduction of malaria and the re-invasion of An. gambiae s.s. These measures also include giving the inhabitants suppressive drugs. Investigations by seasonal IFA tests were recommended. [The authors did not show whether the seven seropositives had a history of movement to an endemic area].

In Sinai, the only available information on the malaria situation comes from past parasitological surveys which were carried out in conjunction with entomological surveys (see under 2.2 above). Gad et al. (1964) pointed out that no accurate data on the malaria
situation in Sinai before 1960 was available. In September 1960, 948 blood slides were collected from the area extending between Rafah and El Arish and at Qossaima. Only six were positive, and all were *P. malarias*. In August-September 1962, the authors carried out a survey covering the northern region of Sinai along the Mediterranean coast from Qantara East to Rafah and including Qossaima and Geiderat, as well as the central region at Nakhl, and the southern region along the coast of the Suez Gulf from Shatt (opposite Suez) to Sharm El-Sheikh. The results were shown as follows:

- The northern region: 3040 blood slides were collected, of which 3 were positive for *P. vivax* (0.1%); two were from El-Arish and one from Qantara East.

- The central and southern regions: 2037 slides were collected, of which 3 were positive (0.15%); 2 were *P. falciparum* (among 25 children 2-9 years old) at El-Wadi, and the third was *P. vivax* in a prisoner at El-Tor.

Thus, the parasite rate in the whole Sinai was 0.12% (6/5077). Some cases were thought not to be indigenous, e.g., the case of the prisoner at El-Tor, since this was the only case found among the prisoners and in the whole locality in which no anopheline larvae or adults were found. The case of Qantara East was probably due to invasion of the locality, which was free of anopheline breeding, by *pharoensis* flying across the Suez Canal. The two cases of *P. falciparum* among children at El-Wadi were considered as truly indigenous, since *sergentii* was the only vector breeding in the locality and found in abundance in houses. Several assumptions were made regarding the origin of the two cases of *P. vivax* at El-Arish. Of these, it was postulated that they were transmitted by the locally breeding *multicolor*, but this species was incriminated only on epidemiological evidence in North Africa. The other possibility was an invasion by *pharoensis* which was supported by the entomological findings by analogy of an outbreak of malaria that occurred in Gaza in 1959, (see 3.4 and 3.5 above). It should be noted that in the northern region there were persons with enlarged spleens. These were among labourers originally from Lower Egypt working temporarily in road and railway repair. Most of them gave a history of schistosomiasis. Based on this survey, the authors considered that malaria in Sinai was not a major problem and recommended the application of malaria eradication measures. Since the Sinai peninsula has vast deserts with little water sources and in many places no suitable anopheline breeding places exist, the malaria eradication operations should, in particular, be directed to certain areas proved in the present survey to have malaria cases, vectors or suspected vectors. These were outlined as follows:

- Geiderat area where *sergentii* and *superpictus* were found breeding;
- El-Tor where *sergentii* was found in abundance;
- Wadi Feiran oases where *sergentii* was recorded;
- localities where *multicolor* was found breeding, e.g., the coastal area between El-Arish and Rafah;
- localities opposite the Suez Canal, namely Qantara and Suez to check the infiltration of *pharoensis* across the Canal.

The suggested measures were larviciding, residual house spraying to act as a barrier against mosquito infiltration across the Canal, and surveillance operations during the first year of attack.

While reporting on their survey of mosquitoes of Sinai, Margalit & Tahori (1973) (see under 2.2 and 3.5 above) showed that the parasite rate in Sinai as recorded from surveys carried out in 1967, was 1.2% (7 positive blood films of *P. vivax* out of 595 examined). This was higher than the rate recorded by Gad et al. (1964). The localities where the positive blood slides were found among the Sinai Bedouin tribes were Wadi Charandai, Wadi Isla and the vicinity of El-Tor. Since *sergentii* and *superpictus* were prevalent in these localities, they were suspected as the major vectors of malaria in these areas.

[These surveys should serve as a guide, as it is time to conduct a thorough entomological/parasitological surveys in view of the extensive ecological changes associated with development in Sinai. On the basis of such surveys, the appropriate control measures can be planned].

In Cyprus, the *Anopheles* eradication campaign which was launched in 1946 succeeded in eradicating malaria. As shown by Zulueta (1974), the campaign was based on the
application of 3-5% DDT in fuel oil to all potential breeding places. The success of the campaign was mostly due to the thorough knowledge of the distribution and habits of the vectors and to well-planned and conducted anti-larval operations. Of the two main vectors, the less widespread sacharovi was completely eradicated, but the more ubiquitous superpictus, although much reduced to a vanishing point was never completely eradicated (see under 1.2 above). The last indigenous case of malaria was detected in 1967 and Cyprus was entered in the WHO Official Register for Malaria Eradication in October 1967. Despite the fact that the island has been free from indigenous malaria in the past 20 years, the country-wide anti-larval operations have been continued as a precaution against the reintroduction of malaria. DDT in fuel oil was gradually replaced by temephos. This produced a collateral effect by giving a general reduction in mosquito breeding, a point of considerable importance in Cyprus, where the tourist industry ranks high in economic terms. Due to disturbed conditions occurring in the summer of 1974, the larviciding operations were disrupted in many parts of the north of the island. As a result, superpictus was detected in August 1974 in breeding places that had been negative in previous years. Its breeding was checked by the reinstitution of anti-larval measures, but in areas where practically all the civilian population had fled, no searches were made or anti-larval measures carried out. Thus, the breeding of superpictus must have gone unchecked during the greater part of the summer. Despite this potentially dangerous situation, no indigenous cases of malaria have been reported since the events of the summer of 1974. Since the south of Cyprus had sufficient insecticides, equipment and personnel, provisions were made by authorities for the larviciding operations to take place in the north starting from April 1975. Shidrawi (1983) (see under 1.2 above) who visited Cyprus in June 1982, compiled records of anophelines found in the island since 1950. No sacharovi has been found since its last record in 1952. With regard to superpictus, the records show its presence only in the Turkish Cypriot side in 1979, while claviger continued to be recorded in the Greek Cypriot side in 1980-1982. Shidrawi also listed the number of imported cases ranging from 2 to 6 in 1980-1982. He concluded that based on the entomological/parasitological records, the malarial potential in the island was very low if not zero, since in the absence [scarcity] of the vector, the few imported cases will not constitute a danger of resumption of malaria transmission. However, he recommended the application of various anti-larval measures for mosquito control in rural and urban areas, as well as maintaining vigilance in seaports and airports. [The question of claviger as a potential vector in Cyprus should be kept in mind since sporozoite-positive specimens had been reported from Cyprus in the past - see under 4.2 above].

The country malaria profile for Cyprus (Unpublished document by Farid, 1987) was shown as follows:

- Population: about 0.7 million
- No. slides examined: 1984 | 1985 | 1986
  - 0 | 0 | 0
- No. positive cases: 1984 | 1985 | 1986
  - 0 | 1 | 2
- No. falciparum cases: 1984 | 1985 | 1986
  - 0 | 0 | 0
- P. falciparum response to chloroquine: not reported
- Vectors of malaria according to vectorial importance - information of insecticide resistance: An. superpictus (potential vector)
- Main vector control measures: larviciding with temephos and biological control by Gambusia
  - Case detection: very good
  - Development of PHC at peripheral level: good
  - Development of PHC at referral level: good
  - Malaria control programme: is part of PHC system mainly for vigilance as malaria has been eradicated from Cyprus
  - Malaria training centres: not available
  - Trained manpower: available
  - Special problems: imported malaria.

From the information communicated to WHO/MAP, data of the malaria situation in Cyprus in 1987 show: (population is given as a mid-year estimate in thousands)
- Total population: 680
- Population of originally malarious areas: 680
- Population of areas known to be free of malaria: 680
In Jordan, as shown by Zulueta & Muir (1972) the Jordanian malaria eradication operations were started in 1958. Since the early work of malaria control that was started in 1949 in the Jordan Valley by the United Nations Relief and Works Agency (UNRWA) for Palestinian refugees in the Near East, it became clear that house spraying with residual insecticides was not sufficient to interrupt malaria transmission and that larviciding was also required, citing Farid (1954), (see under 2.5 above). Judging from the number of cases in 1964 (644 out of 254543 blood slides examined), the situation of the Jordanian programme hitherto was not favourable. This was due to the fact that a decision was taken in 1963, based on the provisions of the previous plans of operations, to withdraw the attack measures that were applied until then to the most vulnerable area, e.g. Jordan Valley and Dead Sea area. The decision was premature as the API in 1963 was 0.34/1000, but it was a clear reflection of the optimism concerning malaria eradication prevailing at that time. When the number of cases rose in 1964, attack operations were reinstituted in all the areas that had been moved to consolidation. Full surveillance operations (with ACD) were maintained, as has been the practice in other malaria eradication programmes when reverting to the attack phase. A steady decline in the number of cases was observed until 1967, when only 28 cases were detected (128192 slides examined). It was envisaged that house spraying and larviciding operations could be withdrawn from most areas under attack. However, this could not materialize because of the war of June 1967 necessitating movement of troops and causing displacement of the civilian population and a general disruption of life in the country. It was remarkable that despite this situation, the Jordanian malaria eradication programme (MEP) has been able to maintain the gains. The only indigenous cases found since June 1967 were among military or para-military personnel, or exceptionally among civilians directly associated with them. Outside the military zones there was no malaria transmission among the civilian population for whom the MEP was responsible, thus what remained in the country was a military malaria problem. To maintain this favourable condition, it has been necessary to keep the most vulnerable areas under house spraying and larviciding. Zulueta & Muir (loc.cit.) anticipated that house spraying and larviciding will have to be applied in relatively large areas of the country. Apart from the expenses involved, this may create a problem of insecticide resistance. One of the main vectors, sergentii which is already resistant to dieldrin, exhibited what could be interpreted as either vigour tolerance or incipient DDT resistance. Laboratory investigations on this phenomenon were inconclusive, but the threat of resistance poses a serious problem if the use of DDT has, as it seems, to be prolonged.

In an unpublished working paper to WHO, Tawfik (1987) reviewed the history of the malaria eradication programme in Jordan since its inception, pointing to the progress made and problems encountered up to the present time. Following the signature of the agreement of malaria eradication in 1956-1957, the operations were carried out in four districts: Yarmouk-Jordan Valley, Balqa, Irbid and Kerak. Since 1970, there have been no indigenous malaria cases in the country. All cases which have been discovered through fever-screening mechanisms were imported from malarious areas in Saudi Arabia, United Arab Emirates (UAE), Oman, Pakistan, India, Sri Lanka and other countries of South East Asia. Since 1967, several factors necessitated the continuation of malaria control and surveillance operations, namely: the unsettled conditions in the West Bank, the continuous travel of Jordanian citizens to malarious countries, the occurrence of some foci of transmission on the Syrian side of the border with Jordan, and the increasing number of Indians and Pakistanis settling in potentially malarious areas in Jordan. The operations and activities that have been maintained were shown as follows:

- Epidemiological surveillance operations: Of the various factors that have contributed to maintaining Jordan malaria-free, the very effective surveillance system which has been developed in recent years, is the most important. Apart from the usual ACD and PCD, a new system has recently been adopted for screening travellers coming from areas for which experience has shown that they are the origin of most of the imported cases in
Jordan. Screening begins on board aircraft coming, for example, from Saudi Arabia: passengers are given cards to complete (in English and Arabic). If the passenger came from a well-known malarious area (e.g., Giza, Qunfudah, Najran, Khaybar) and has fever or there is a suspicion of malaria, a blood slide is taken and presumptive treatment given.

As the address in Jordan is shown on the malaria cards, these passengers as well as those coming from other malarious areas, are followed up and radical treatment is given if necessary. A similar arrangement has been made for the examination of travellers coming from Saudi Arabia by road at the border post of Midawara. Regarding passengers from Oman and UAE, whether in a direct or a connecting flight, they are requested to complete a malaria card upon arrival in Amman airport where further action is taken if required. The same arrangements are made at the road border posts of Ramtha and Um-el-Jamal. Passengers from certain areas of Egypt are also screened by the same procedures. Special measures are taken concerning Pakistani and Indian nationals, in view of their increasing numbers who come to Jordan to work as labourers especially in recent years. All Pakistani and Indian labourers and their families receive full radical treatment and must be in possession of a malaria card showing that such treatment has been administered, otherwise permission to work is refused. To implement all the above measures, the malaria eradication programme keeps permanently on duty 1-6 agents at Amman airport, one at Midawara, one at Ramtha and one at Um-el-Jamal, as well as one agent at Amman railway station for arrivals by train. In addition, a number of agents are assigned to follow up travellers coming from malarious areas. This is no doubt a considerable effort, but the results of recent years have been rewarding. However, a small loophole in the surveillance or the larviciding or spraying operations (for example, the huts where the cases lived had not been sprayed) can lead to resumption of malaria transmission in a potentially highly malarious area such as the Kerak Lowlands. This shows the great risks of malaria that still exist in Jordan. On the other hand, the duties of the staff of the malaria department have been expanded to cover other diseases. The malaria surveillance agents who are distributed all over the malarious areas in the country make house-to-house visits fortnightly, looking for fever cases. During these visits, they also collect urine samples from any person, whether national or expatriate, who is complaining of haematuria. The urine samples are sent to peripheral or central laboratories for screening for schistosomiasis. If positive, the surveillance agent is instructed to give the appropriate drug and follow up the case until it proves negative. The surveillance agents also look for any skin lesions in local inhabitants, and refer such cases to the government general practitioners for re-examination and for providing treatment and follow-up for those found positive for cutaneous leishmaniasis which is endemic in some areas of Jordan. Another task of the malaria surveillance teams is to collect sputum samples from any suspected tuberculosis case. The samples are then sent to the tuberculosis centre for examination and providing treatment and follow-up of positive cases.

- Larviciding and house spraying operations: After more than 25 years, larviciding continues to be the principal anti-vector operation. Since the early work of Farid (1954 & 1956) – (see under 2.6/2.7 above), it has been generally accepted that residual house spraying alone cannot interrupt malaria transmission in Jordan, due to the outdoor sleeping habits of the local inhabitants and the outdoor-resting of the two most important vectors, sergenti and superpictus, hence the need for larviciding operations. Although larviciding is more expensive, it has been found to be more effective than residual house spraying under the conditions prevailing in Jordan. Since the re-institution of attack measures throughout the malarious areas of Jordan in 1965, the amount of larviciding (supplemented by some drainage work in the Kerak Lowlands) has not substantially changed. What has been changed is the larviciding agent used; temephos 500E replaced 0.5% DDT in diesel oil. In view of the absence of malaria transmission, the possibility of discontinuation or reducing vector control operations was considered, particularly with respect to house spraying. The prolonged use of this method has produced, as would be expected, some reluctance among the local inhabitants, particularly the younger generations who have not seen the past ravages of malaria. Despite this, the average spraying coverage during 1973 and 1974 was 86 and 88% respectively. This degree of coverage could be obtained through the efforts and persistence of those in charge of the operations. However, the discontinuation of house spraying would require a reinforcement of the more expensive larviciding operations. In this connection, a question arises whether larviciding alone can guarantee the maintenance of complete interruption of malaria transmission. When all these factors were taken into account, the conclusion arrived at, is that as long as the receptivity and vulnerability to malaria remain as high
as they are now, larviciding and spraying operations will have to be continued on approximately the present scale (see further information given at a later date below). As with the surveillance agents, the work of larviciding teams has been expanded to cover vector and intermediate hosts of other parasitic diseases. Labours in charge of larviciding operations who acquired experience with different snails are asked to collect any suspected Schistosoma haematobium snails and send them to the entomological section for identification. If the presence of haematobium snails is confirmed, it is then the duty of the operational section to deal with them using the appropriate molluscicide. Another main task of the operational section is to apply DDT house spraying to eliminate Phlebotomus sandflies, vectors of cutaneous leishmaniasis in some areas of Jordan. The identification of sandflies and estimation of their density in different parts of the country remain the responsibility of the entomological section.

- Entomological activities: One of the main tasks of entomological activities is to determine the susceptibility level of malaria vectors to the insecticides used. An. superpictus has so far not shown any sign of insecticide resistance. On the other hand, recent tests suggest a low degree of DDT resistance in sergentii in addition to the already existing dieldrin/HCH resistance. More tests will be done to verify the level of DDT resistance in sergentii. Larval tests showed that both sergentii and superpictus are susceptible to temephos. In addition to entomological activities related to malaria, the entomological section identifies the species of schistosomiasis snails and sandfly vectors of leishmaniasis and estimates their densities in different areas of the country. The section also conducts training courses in entomology.

- Special operational problems: The Jordanian programme has faced some difficulties along the borders. An example comes from the Yarmouk Valley where sacherovi has recently been found. In previous years, the Jordanian larviciding teams covered the Syrian as well as the Jordanian sides of the valley. Not only has this been discontinued, but the presence of mine fields has considerably restricted the larviciding operations on the Jordanian side. A similar situation exists near Safi, at the southernmost end of the Dead Sea where, due to the presence of mines, sergentii breeding has remained unchecked in recent years. Despite these constraints, there has been no malaria transmission during the past few years in either of the two above mentioned areas. A further problem is related to the Rutenberg dam at the Yarmouk river close to its junction with the Jordan river as explained under 2. below.

The country malaria profile of Jordan (Unpublished document by Farid, 1987) was shown as follows:

- Population: about 3 million
- Population at risk: nil
- No. slides examined
  - 1984: 98,682
  - 1985: 131,228
  - 1986: 125,063
- No. positive slides
  - 1984: 312
  - 1985: 458
  - 1986: 297
- No. P. falciparum cases
  - 1984: 24
  - 1985: 63
  - 1986: 67
- P. falciparum resistance to chloroquine: nil
- Vectors of malaria according to vectorial importance - information on insecticide resistance: An. sergentii - dieldrin/HCH potential vectors
  - An. superpictus
- Main vector control measures: DDT house spraying and temephos larviciding.
- Case detection: Very strong surveillance mechanism through ACD and PCD, follow-up of cases, and examination of labours upon entry.
- Development of PHC at peripheral level: good
- Development of PHC at referral level: good
- Malaria control programme: is a vertical one
- Malaria training centres: not available in the country - Jordan relies on WHO fellowships for training staff
- Trained manpower: available
- Special problems: imported malaria.

From the information communicated to WHO/MAP, data of the malaria situation in Jordan in 1987 show: (population given as a mid-year estimation in thousands).
- Total population: 3,225
- Population of originally malarious areas: 1,976
- Population of areas claimed to be free from malaria: 878
- Population under malaria control programme:
- Population protected by anti-vector measures: 755
- Population under consolidation phase: 344
- Population under surveillance: 399
- No. slides examined: 115, 151
- No. positive slides: 281 (92 P. falciparum & 189 P. vivax - all imported).

The information also shows that Jordan still remains free of malaria transmission as not a single indigenous case has so far been detected. All the P. falciparum imported cases that have been recorded are susceptible to chloroquine. In 1987, DDT house spraying and temephos larviciding have been discontinued in some trial areas. This was done following the recommendations of the Workshop for Improvement of Malaria Control through Applied Field Research that was held in Amman during 31 March-12 April 1984. (WHO, 1984). The trial areas were selected in the Jordan Valley and Kerak Lowlands, where DDT spraying and larviciding operations have been discontinued in certain parts and larviciding only suspended in others. In all other areas, DDT spraying and larviciding are continuing.

In Israel, Saliternik (1978) summarized the history of malaria in Palestine and the introduction of vector control methods since 1918. In 1948, when the State of Israel was established, there were 1,172 fresh cases of malaria detected. In 1949, an Antimalaria Division was established in the Ministry of Health to deal with the planning, organization, implementation and supervision of malaria control (and later malaria eradication operations) in Israel. In 1959, only 36 malaria cases were recorded. Nevertheless, a malaria eradication campaign was conducted between 1960-1966 in cooperation with WHO. By 1962, malaria was practically eradicated from Israel.

Saliternik (1977a) explained how the malaria eradication campaign in Israel employed various methods that deviated from the WHO principles as shown in the following:

(a) There was no malaria eradication Ad hoc committee formed, nor were there malaria regulations issued.

(b) The house-to-house ACD method was never established. Hence, there was no presumptive treatment given to suspected cases. ACD was only carried out among selected population groups such as Bedouin nomads, immigrants from malarious countries, and students from African countries.

(c) PCD was the normal surveillance procedure, because of the high physician-population ratio (about 1:1400), and over 80% of the population benefitted from health insurance. Moreover, medical personnel were malaria-conscious and most malaria cases were hospitalized.

(d) Induced malaria cases were extremely rare, due to selective screening of blood donors as well as keeping transfusion blood refrigerated 10 days before use.

(e) No introduced cases of malaria occurred due to perfect vector control.

(f) Regular DDT house spraying was limited to selected localities, such as those situated along the Syrian and the Jordanian borders and the Dead Sea strip as well as foci of malaria parasite carriers. Spraying was timed according to the seasonal prevalence and flight range of the vectors. On the other hand, larval control in Israel reached a high level of perfection through fixing, mapping, treating and surveying all breeding places. For larval control residual insecticides were not used in order to avoid selective pressure for resistance. As a result of these measures, sacharovli, the main vector of malaria in Israel, completely disappeared.

(g) Chemoprophylaxis was given during 1959-1962 only to inhabitants of the Dead Sea strip and to the numerous visitors (about 60,000) who slept on the shores of the Dead Sea.

Through all these measures, malaria eradication was practically achieved by 1962.
Salternik (1977b) further elaborated on vector control methods. For larviciding operations, Malariol was used which contains fish oil to increase the oil spreading power. Indoor DDT spraying was carried out after 1945 in selected localities, such as settlements along the borders, foci of malaria carriers, new settlements established in previous malarious areas, settlements where the vectors had been encountered, and dwellings of malaria patients. Only a 5% DDT solution in kerosene was used for house spraying at a rate of 40 cc/m². The spraying was timed in accordance with the bionomics, flight range and seasonal appearance of the local vectors. Vector control was directed to four anopheline species which were proved to be important vectors of malaria, each one at a different period from April to December. Their characteristics, habits and specific methods for their control were shown as follows:

(a) An. sacharovi: This species was the main vector of malaria in Israel in spring and late autumn (in the Huleh area) until 1958. It used to breed in more or less stagnant and unshaded waters covered with horizontal aquatic vegetation. It was regarded as anthropophilic/endophagic and endophilic species. Early investigations showed that females of sacharovi accumulated and stored fat body before winter and then mass migrated in late autumn causing malaria outbreaks in Rosh-Pina, 15 km from the Huleh breeding swamp, usually free from Anopheles and malaria in other seasons (see more details under 1.4 and 1.5 above). The specific control measures were:

- Avoidance of cutting dense vertical vegetation in order not to expose the water surface to light.
- Elimination of aquatic vegetation: Ranunculus, Potamogeton, Myriophyllum and Ceratophyllum.
- Introduction of Tilapia fish into pools; the fish ate and destroyed the horizontal vegetation in stagnant waters.
- Frequent water level variation in stagnant waters.
- Flooding some breeding places in order to interrupt breeding through raising the water salinity to above 0.8%.
- Emptying rain water pools in April.
- Flushing of slow water.
- Larviciding operations.
- Large scale drainage activities.
- DDT spraying was applied in April, and again in October if necessary.

(b) An. sergentii and An. superpictus: Both species remained very important vectors. Their breeding habits, dispersal, and resting habits were summarized from previous observations carried out in Israel (see under 2.2, 2.4, 2.5 and 2.6/2.7 above). The methods of control of superpictus were similar to those of sergentii as shown in the following:

- The introduction of the larvivorous fish, Gambusia affinis into mosquito breeding places.
- The clearing and cleaning of water beds to accelerate the water flow to over 20 cm/second.
- Weekly drying up of the water beds by diverting the water flow to different directions.
- The erection of dams for periodic flushing of water beds.
- The prevention of overflowing and seepages.
- Larviciding operations.
- Small scale drainage activities.
- The application of DDT spraying in June against superpictus and in September against sergentii. Investigations showed, however, that DDT spraying against sergentii was incapable of preventing malaria transmission, owing to its exopnagic and exophilic behaviour. It was necessary, therefore, to continue the systematic larviciding operations on a countrywide scale.

(c) An. claviger: This species used to be an important vector of malaria in certain localities of Israel, in view of its habit of breeding in shaded and cool waters of the courtyard cisterns, thus coming in close contact with man (see under 4.2 above). The control measures for this species were:

- Hermetic sealing of cisterns and wells.
- Provision of piped water supply.
- Larvicidal operations.
Naggan, Kark & Egosz (1973) reported the results of their study of 239 malaria cases that were reported to the Ministry of Health and the Medical Corps in Israel during 1967-1971 (3 in 1967, 17 in 1968, 21 in 1969, 56 in 1970 and 142 in 1971) from Israel and the Occupied Territories. Epidemiological investigations were carried out in conjunction with 88% of the cases. The clinical data were taken from the hospital files of 85% of the cases that were hospitalized during 1967-1970. Only the cases for which the clinical diagnosis was confirmed by microscopic identification of the malaria parasites in blood were included in this study. The majority of patients were soldiers and reservists undertaking active reserve duty. All cases were P. vivax except four: 2 P. falciparum, 1 P. malariae and one mixed (P. vivax + P. malariae). Epidemiological investigations pointed to the northwestern part of Sinai, along the Suez Canal, as the main site of infection, as 90% of the patients for whom information was available became sick after a sojourn in Sinai. At least two patients became ill after a stay in the Golan Heights, but there were no proven cases from the Jordan Valley. Because of the high mobility of the soldiers and civilians, it was hard to determine precisely the incubation period.

There was a group of 61 patients who stayed in Sinai only once during the year prior to the onset of their illness and whose stay was not longer than three months, was selected for determining the incubation period. The minimal incubation period was defined as the time between departure from the malarious area to the onset of the clinical symptoms of the first malaria attack. Graphical presentation of data showed bimodal distribution of the cases, indicating two incubation periods: one month in 13 patients, and 5-15 months in 48 patients. Most of the cases became infected during the summer months, mainly between July and September. Annual morbidity occurred from April to October with a complete absence of new cases between November and March. Most of the cases received proper treatment (chloroquine for 3 days and primaquine for an additional period of 15 days).

Long incubation periods of P. vivax have been described from several areas in South East Asia and Europe but never in Israel. Only seven patients had relapses, because of inadequate treatment or misdiagnosis. Referring to entomological surveys carried out previously in Sinai by Egyptian scientists and Israeli workers (see under 3.5 above), the authors assumed that pharoensis was the probable vector which was shown to have a long flight range. As no breeding places were found in the eastern side of the Suez Canal, pharoensis breeding must have occurred on the western side of the Canal in swamplike areas along the fresh water canal, running parallel to the Suez Canal.

Pener & Kitron (1985a & b) commenting on the reappearance of sachevori and the gradual increase in the number of its breeding sites in Israel (see under 1.5 above) together with the influx of malaria imported cases, recommended that continuous surveillance of vector and parasite carriers should be maintained and even strengthened.

As shown by WHO (1979, Wkly Epidem. Rec.), the number of malaria cases recorded in Israel in 1977 was 28 among the civilian population, as compared with 15 cases in 1976 and 9 cases in 1975. All patients acquired the infection abroad (64.3% in Asia, 28.6% in Africa and 7.1% in the Western Pacific. P. vivax was predominant (16 cases) while P. falciparum was recorded in 11 cases compared with two cases in 1976.

Further information given by WHO (1982, Wkly Epidem. Rec.) showed that in the past five years (1976-1980), 117 malaria cases were diagnosed in Israel. With no exception, all were imported cases, of which 74 were among Israeli citizens returning from abroad, 19 in foreigners visiting Israel and 24 in new immigrants. The distribution of cases by place of acquisition was as follows: African countries, 87(74.3%); Asian countries, 21(17.9%); South or Central America, 6(5.1%) and very few from other parts of the world. The majority of the malaria cases were due to P. vivax (61.5%) versus 32.5% P. falciparum, 0.9% P. malariae, 3.4% P. ovale and 1.7% mixed infection. Continued vector control and surveillance activities, including case detection, radical treatment, epidemiological investigations and constantly informing of the medical services are the basic methods used to maintain the country free from local transmission.

From information communicated to WHO/MAP, the data on the malaria situation and anopheline surveys showed that there were 94 cases of malaria recorded in the civilian population in 1987, constituting a significant increase over the incidence in 1986 (36 cases). All cases were imported: 83 (88% from Africa - 53 from Ethiopia) and 10 (11%) from the Far East. The most common parasite was P. falciparum (58.5%) followed by P. vivax (28.7%), and there were small mixed infections (6.4%) while some infections remained undetermined (6.4%). For the first time in Israel a probable case of airport
malaria was recorded. The patient was a 26-year-old Skyhawk electrician who worked for one night in September 1987 at a site situated a few metres from the terminal where cargo planes arriving from Asian and African countries were unloaded. It was assumed that the infection was contracted that night through the bite of an Anopheles mosquito infected with *P. falciparum* which arrived in Israel in the cargo hold of a plane originating in an endemic area. From anopheline surveys in the whole country, 347 Anopheles breeding places were recorded in 1987, a 30% increase over the record of 1986 (248 breeding places). The largest numbers of positive breeding places were in Akko and Tiberias sub-districts. Of the 347 breeding places recorded, 8.3% were positive for *sacharovi*, 43.8% for *claviger*, 13.8% for *supercitius*, 21.9% for *sergentii* and the remaining for other anophelines.

In Lebanon, Zulueta & Muir (1972) showed that in 1951 a joint WHO/Government malaria control demonstration project was established simultaneously with similar projects in Jordan, Iraq and Syria. When the global malaria eradication policy was adopted by WHO in 1955, these four control programmes were converted into nation-wide malaria eradication programmes. This was started in Lebanon and Syria in 1956, in Iraq in 1957 and in Jordan in 1958. In Lebanon, steady progress was made as all areas originally malarious with a population of 856,000 reached the maintenance phase by 1970. In that year only 25 malaria cases were detected out of 42,620 blood slides examined. Most of these cases were imported and none was indigenous. The reason for this success was that the malaria eradication programme was superimposed in 1956 on a successful malaria control demonstration project, which had thoroughly studied the malaria situation in the country and had thus laid a solid background for the eradication campaign. Although health facilities in Lebanon, particularly in rural areas, may not have been adequate, the ratio of 1 physician per 230 inhabitants indicated the availability of qualified medical personnel. Moreover, the standard of living in Lebanon was such that a person suffering from malaria will not remain for a long time without seeking medical advice and treatment, usually from a private physician. These conditions were not always found in Jordan, Iraq and Syria. In fact, it was among Syrian immigrant labourers that the last indigenous cases were found in Lebanon during an outbreak in the Nahar Beirut area in 1962–1963.

Since then, practically all cases found in Lebanon were imported, mostly from Africa.

Due to the prevailing conditions, only limited information is available on the malaria situation in Lebanon in recent years. The country malaria profile of Lebanon (Unpublished document by Farid, 1987) shows the following:

- **Population**: about 3 million
- **Population at risk**: Nil
- **1984** | **1985** | **1986**
- **No slides examined** | 31391 | 650 | 2193
- **No. positive slides** | 18 | 8 | 3
- **No. *P. falciparum* cases** | 1 | 1 | 0
- ***P. falciparum* resistance to chloroquine**: Nil
- **Vectors of malaria according to vector importance – information on insecticide resistance**:
  - *An. sacharovi* – DDT; dieldrin/HCH; fenitrothion
  - *An. superpictus*
- **Main vector control measures**: information not available due to the prevailing conditions.
  - Case detection: PCD only.
  - Development of PHC at peripheral level: information not available
  - Development of PHC at referral level: information not available
  - Malaria control programme: is integrated in health services
  - Malaria training centres: Not available
  - Trained manpower: Available
  - Special problems: Prevailing conditions.

The limited information communicated to WHO/MAP on the malaria situation in Lebanon in 1987 showed that, of the total population of 3 million the population of the originally malarious areas, 1,019,000 were claimed to be free from malaria. Of 33,989 blood slides collected in 1987, only two were positive (1 *P. falciparum* and 1 *P. ovale*).

In Syria, the antimalaria activities were reviewed and evaluated up to 1980 as shown in an unpublished report to WHO by Khawam, Onori & Eshghy (1980). In 1949, a malaria
control project was started in a rural area about 20 km east of Damascus comprising 14 villages with a population of 20 000. Three years of DDT house spraying led to interruption of malaria transmission in an area where nearly 60% of the population had been suffering from malaria. In view of these excellent results, the Government decided to extend control operations to the whole of Damascus and Deraa provinces. In 1953, operations were extended to some areas in Homs, Hama, Aleppo provinces involving a population of 380 000. In 1956, a plan of operations for malaria eradication was signed and a National Malaria Eradication Service (NMES) was established. DDT spraying operations were started in the same year but without any geographical reconnaissance, while the delimitation of malarious areas was based on some malarialmetric surveys carried out in different areas of the country. Initially, the programme marked consistent success, but in the late 1960's foci of transmission re-appeared in areas which had been freed from malaria, and new foci were discovered in areas considered potentially non-malarious. The situation became critical in 1968, when DDT resistance was found in all areas of \textit{sacharovi} distribution. With dieldrin replacing DDT and the distribution of antimalarial drugs in areas of highest transmission, the situation markedly improved during 1968-1972. Interruption of transmission was achieved in several provinces and very large and important reservoirs of infective cases as in Ghab valley (Hama province) and Rakka province responsible for the flare up of secondary foci, were depleted. Limited foci of transmission, however, persisted especially in Aleppo and Deraa provinces. By the end of 1972, \textit{sacharovi} became resistant also to dieldrin after four rounds of dieldrin spraying at a dosage of 1 g/m² in each (two rounds annually). Subsequently, malaria transmission was resumed. Commencing in 1975, malathion in the form of 50% water dispersible powder (wdp) at a dosage of 2 g (active ingredient)/m² in 2-3 rounds annually replaced dieldrin spraying. As a result of the unpleasant smell of this formulation, there was a high rate of population refusals. Thus, a 50% emulsifiable concentrate (EC) was introduced starting from 1978. For studying the malaria situation in Syria during 1972-1979, the ABER and API were examined. The data showed that the number of slides collected decreased year after year with a more marked drop in 1975 and 1979. The deterioration of surveillance activities was reflected by the downward trend of the ABER, while the corresponding API showed a constant increase. Comparison of the number of slides examined and cases discovered in each province during 1 January-31 July 1975 with the corresponding period in 1979 showed a consistent improvement in all provinces except Deraa, Hama, Lattakia and Hassakeh where indigenous cases were still being observed. No accurate information was available on the development and extent of a malaria epidemic that progressed in the Ghab valley in recent years where no properly supervised control activities could be undertaken in 1980. In the light of the above analysis, the epidemiological situation in Syria in 1980 was considered to be serious due to the persistence of the malaria epidemic in the Ghab valley and the presence of active foci in Deraa, Lattakia and Hassakeh provinces. In view of the worsening epidemiological situation from 1975 onwards together with the deterioration of surveillance activities during 1972-1980, immediate remedial measures were needed to prevent massive resurgence of malaria in Syria. Several administrative, operational and to a minor extent technical problems that contributed to the deterioration of the epidemiological situation were described. Some of these seem to have persisted in later years as shown below. A plan of action for the activities to be undertaken in 1981 was prepared.

In an unpublished report to WHO, Eshghy (1981) indicated that \textit{sacharovi} remained resistant to DDT and dieldrin/HCH but susceptible to malathion, and also to propoxur, but a small survival was recorded in tests made with fenitrothion. In a village scale trial, malathion EC applied at a dosage of 2 g/m² was effective for less than one month on cement surfaces, but there were indications that its impact on vector densities and longevity lasted for a longer period on mud surfaces. The impact of malathion EC needs to be assessed epidemiologically. In view of continued malaria transmission along the frontier with Turkey, some observations were carried out in June 1980 in Malikya (northeast of Syria), Hassakeh province and in Darkoush (northwest), Idlib province. The border between Syria and Turkey is composed mostly of fertile land. The Syrian border with Turkey extends over 808 km and a number of villages are at malaria risk. The Syrian villages are situated opposite the Turkish villages and the two sides often share the same breeding places, and due to seasonal crop cultivation near breeding places the density of anophelines [\textit{sacharovi} and \textit{superpictus}] increases in some years. Since the spraying operations were not applied at the right time and were defective both in dosage and coverage, the problem of persistence of malaria transmission continued. Moreover, most of the inhabitants sleep outdoors during June-August, thus most biting occurs outdoors during the transmission season (see also more details by Eshghy, 1983, under 1.6.1.7 above).
In an unpublished working paper to WHO Markin (1984) recalled the main problems which faced the malaria eradication programme in Syria since 1980 as shown in the following:

(a) Administrative problems

- Decentralization of administrative powers to the provincial health authorities: This was implemented without paying much attention to the provincial manpower resources which were not sufficient to take over these major responsibilities. Both the provincial health directors and their assistants for preventive medicine are not always fully acquainted with malaria activities and do not provide the peripheral malaria centres with the necessary logistic and administrative support. Accordingly, there is discordance between the NMES in Damascus and the provincial health authorities who are responsible for all the antimalaria activities at peripheral level. As a result, discipline has become lax.

- The annual budgetary provisions for the NMES could not cope with the galloping inflation and continuous rise in the cost of living. Wages and travel allowances are no longer realistic and attractive to personnel engaged in spraying and surveillance. Funds are not available to purchase new vehicles; the old cars are subject to frequent breakdowns, hence field supervision is fragmentary and inadequate.

- With malaria gradually disappearing in most of the provinces, malaria personnel and vehicles are utilized for the prevention of other communicable diseases at the expense of the NMES activities, without paying much attention to the antimalaria operational needs including the remedial action to prevent the resurgence and spread of the disease.

(b) Operational problems

- The socioeconomic status of the rural population has greatly changed. Hence, the rate of refusals of house spraying has been increasing particularly after the introduction of malathion in 1975, although the change to malathion EC has partly solved the problem. After a period of trial, it has been decided to use permethrin on a larger scale.

- Shortage of qualified personnel has been partly responsible for the poor supervision of all field activities. The available microscopists and insect collectors have been given refresher training. New cadres need to be recruited from the Institute of Sanitarians to be trained in malaria work so that they can eventually form the expertise required for the continuation of the programme.

(c) Technical problems

- The main problem is the physiological resistance in sacherovi to DDT, dieldrin/HCH and fenitrothion, but this has been solved by the use of malathion and more recently permethrin.

- Outdoor transmission when the people sleep outdoors because of hot weather during the transmission season.

From the unpublished report to WHO of Sadek (1984), permethrin house spraying was applied in 1983 at different dosages and rounds according to the ecological conditions prevailing in the northeastern and southwestern regions of Syria; one round in June at 400 mg/m² in villages along the Turkish border from Idlib to Malkiya in June, and two rounds (May and August) each at 250 mg/m² in Lattakia, Hama, Damascus, Deraa and Quneitra. The quality of spraying was not as good as it should have been due to lack of training and supervision at all levels. Nevertheless, coverage was satisfactory because of the low rate of refusals. On the other hand, permethrin was applied without geographical reconnaissance (GR) in areas under insecticidal coverage. This hampered the proper evaluation of antimalaria activities and the impact of the great socioeconomic changes. Thus, simple GR was strongly recommended not only for the spraying operations but also for other activities. For comprehensive entomological evaluation of permethrin spraying, two small villages of similar ecological conditions 5 km apart were selected at 70-100 km from Damascus: one to represent the sprayed area and the other to serve as control in an unsprayed area. The selection of these villages not far away from Damascus
was dictated by the shortage of transport. Although they were not within areas of malaria foci under parasitological assessment, they were both receptive. Permethrin (EC) was applied on 5 September 1983 in the treated village at a target dosage of 250 mg/m². Houses were scattered and built of cement bricks plastered with cement or covered with lime-wash. Animal sheds were built of mud adjoining houses or nearby. Several entomological techniques were employed simultaneously in both villages from September to November, viz: estimation of the indoor resting density of *sacharovi* by PSC, trap mortality among mosquitoes exiting in window traps, determination of the parous rate by Detinova's technique, and contact bioassay tests (in the sprayed village). In addition, the susceptibility of *sacharovi* to different insecticides including permethrin was tested. The density of *sacharovi* in the sprayed village as estimated by PSC was 53.5/room one week before spraying, dropped to 0.7 after 8 days of spraying and remained low (6.7-6.8) for more than one and a half months post-spraying, while the density remained high in the untreated control village. Thereafter, there was a marked drop in density in November, but this was attributed to cold conditions rather than the effect of permethrin, since a parallel decrease was observed in the control village. Observations by window traps were inconclusive as the numbers of *sacharovi* collected from the sprayed village were very small (see under L.6/L.7 above). The effectiveness of permethrin (EC) as indicated by bioassay tests was not of a long duration: after the 3rd week post-spraying, the mortality was reduced from 63.5% to 18.1% and 8.4% after one and a half months and two months respectively, despite doubling the exposure time. Whitewashed surfaces proved to be better substrate than cement, giving a residual effect of about two months. Mud gave the best results, remaining effective for more than two and a half months. Susceptibility tests indicated that *sacharovi* was still susceptible to malathion. With permethrin, exposure to 0.25% concentration for one hour gave 91.2-100% mortality, indicating the presence of tolerant individuals for which confirmatory tests should be conducted [see below].

Sadek further attempted to use the method proposed by Garrett-Jones & Grab (1964) for assessing the insecticidal impact on the vectorial capacity, but with modification. Instead of calculating the density factor of the impact as a derivative of the expectation of life from data of the sprayed and unsprayed villages, Sadek used the indoor resting densities indices directly estimated by PSC in the two villages. The use of PSC data instead of man-biting rates was due to administrative difficulties that hampered the night work. The following data were utilized:

<table>
<thead>
<tr>
<th>Period of assessment</th>
<th>Density index per room</th>
<th>% Parous</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sprayed</td>
<td>Unsprayed</td>
<td>Sprayed</td>
</tr>
<tr>
<td>One week before spraying</td>
<td>53.5</td>
<td>67.0</td>
<td>-</td>
</tr>
<tr>
<td>Mean post-spray(8-66 days)</td>
<td>4.13</td>
<td>37.03</td>
<td>41(65 dissected)</td>
</tr>
</tbody>
</table>

The density factor was calculated as follows: \( \frac{BC}{AD} \)

where:
- \( A \) = unsprayed area before spraying;
- \( B \) = unsprayed area after spraying;
- \( C \) = sprayed area before spraying;
- \( D \) = sprayed area after spraying.

Hence the density factor of impact (ratio unsprayed:sprayed) = 7.16:1.

The longevity factor was calculated from the parous rate. The duration of the extrinsic cycle for *P. vivax* (9 days) was derived from the graphs shown in Macdonald (1957) according to the mean temperature in the observation area during September-October. Based on the assumption that the mean duration of the gonotrophic cycle in *sacharovi* was 2.5 days, the probability of daily survival and expectation of infective life were derived from the graphs shown in Garrett-Jones & Grab (1964). Thus, the longevity factor of impact was calculated as 2.76:1. Accordingly, the total impact of permethrin would be 7.16 x 2.76:1 = 19.76:1, i.e., the rate of distribution of infective bites per case per day by *sacharovi* population would be about 20 less than in the absence of spraying.
Eshghy (1986) in his unpublished report to WHO listed a series of susceptibility tests carried out on sacharovi with different insecticides in several provinces of Syria during July-September 1985. The results of these tests were communicated to WHO, a summary of which is shown in Table 12. Some of these tests indicated the presence of permethrin resistance in sacharovi in certain localities in Hama and Aleppo provinces. [The extent of this resistance in areas under permethrin spraying in Syria needs to be delimited and final confirmation should be obtained from recognized laboratories. If confirmed, well-organized entomological/parasitological observations should be conducted to determine the operational implications of permethrin resistance].

The country malaria profile of Syria (Unpublished document by Farid, 1987) was shown as follows:

- Population: About 11.6 million Population at risk: 4 million
- No. slides examined 1984 1985 1986
  - No. positive slides 442 050 435 273
  - No. P. falciparum cases 5 2
  - P. falciparum resistance to chloroquine: Neither suspected nor reported.

V. falciparum according to vector importance - information on insecticide resistance:

- An. sacharovi - DDT/dieldrin; fenitrothion
- An. superpictus
- Main vector control measures: House spraying with permethrin and temephos larviciding.
- Case detection: Both ACD and PCD exist
- Development of PhC at peripheral level: fairly developed
- Development of PhC at referral level: fairly developed
- Malaria control programme: is integrated with other parasitic disease programmes, decentralized and vertical.
- Malaria training centres: A nucleus exists in Damascus for sub-professional staff, mainly microscopists.
- Trained manpower: Insufficient
- Special problems: Agricultural practices, vector resistance; experienced key personnel are lacking.

From information communicated to WHO/MAP, data of the malaria situation in Syria in 1987 show: (population given as a mid-year estimate in 1000s)

- Total population: 12 036
- Population of originally malarious areas: 6.500
- Population of areas claimed to be freed from malaria: 4 000
- Population under malaria control programme: 2 500
- Population protected by house spraying: 500
- Population protected by other anti-vector measures: ?
- Population under surveillance: 12 036
- No. slides examined: 231 344
- No. positive slides: 150
- Estimated total number of cases: 150

The classification of cases of 1987 showed that 55 were indigenous, 80 relapses, 14 imported and 1 introduced. All indigenous cases were P. vivax. Of the 14 imported cases, five were P. falciparum. The imported cases originated in tropical Africa, South East Asia and Yemen. The distribution of malaria foci in Syria was shown as follows: Hassan Kabbir, Aleppo (86), Lattakia (27), Maikya on the northeastern border with Turkey on Dejla river (20), and there were sporadic cases in Tartous (1), Hama (1) and Raqqa (1).

2. Resistance of P. falciparum to chloroquine in the Mediterranean Basin

The most up-to-date records of resistance of P. falciparum to chloroquine in the world have been projected in a map by WHO(1989, Wkly Epidem. Rec.) as shown in Fig. 11. As can be seen no chloroquine resistance in indigenous P. falciparum cases have so far been recorded in countries of the Mediterranean Basin. Only one imported case of P. falciparum resistant to chloroquine was reported from Algeria [see under (11), 1 above].
Malaria and its control in water-resources and other development projects

Many large dams have been constructed in several countries of the Mediterranean Basin as can be seen in the World Register of Dams (1978). A literature search including the comprehensive bibliography of Deom (1982) and the available unpublished reports covering studies on malaria specifically or as a component of public health activities in water-resources projects in countries of the Mediterranean Basin under malaria control or in advanced maintenance phase revealed only limited information except in a few cases where more details have been given. As part of development, the available information on the implications of highway construction is also summarized here.

In the USSR, two articles were presented in the meeting of the International Scientific Project on Ecologically Safe Methods for Control of Malaria and its Vectors dealing with prevention and control of malaria in hydraulic engineering projects and irrigation schemes. As these articles are quite detailed, they can be read in the original. Only orientation to their contents is given here. Timofeeva (1980) after introducing the problem of formation of ponds in the course of construction of water reservoirs and in relation to breeding of malaria vectors, discussed the following aspects:

- The influence of various parts of water reservoirs on mosquito breeding.
- The necessity of malarialogic forecasts and their significance for antimalaria measures.
- Selection of dam construction sites and marking of normal backwater level.
- Antimalaria hydro-technical measures.
- Selection of the site of human settlements in the zone of water reservoir influence.
- Prophylactic and treatment measures in places where the malaria situation is expected to deteriorate.
- Vegetation control during the period of water reservoir exploitation.
- Prevention of mosquito breeding in other hydraulic schemes.
- The significance of sanitary-epidemiological supervision during construction and exploitation of hydraulic schemes.

The other article was presented by Bandin (1980) dealing with the effect of changes in ecological conditions on anopheles fauna and density under the influence of human economic activity. After introducing the experience in the USSR, Bandin discussed the following aspects:

- Antimalaria hydrotechnical works.
- Sanitary supervision to prevent waterlogging.
- Zooprophylaxis.
- Selection of sites for human settlements and their design.
- Mosquito breeding in irrigated agricultural areas.
- Factors influencing the malaria situation in irrigated agricultural areas: social factors; parasitological factors; entomological factors.
- Duties of entomologists and sanitary hydrotechnologists.

In Turkey, Lassen (1982) in an unpublished working paper to WHO, described and reviewed the malaria situation in the area of Chukurova/Amikovasi in Turkey, where major agricultural development has been taking place. The area covers the provinces of Icel, Adana and Hatay in the south of Turkey. The area is surrounded by the Taurus mountains in the north (reaching an altitude of 3585 m), the Anti-Taurus mountains in the east and the Mediterranean in the south. In the 1960's, a large project known as Lower Seyhan Irrigation Project was established, permitting agricultural and hydroelectric development in the area. The lower Seyhan plain is limited in the east and west by the Seyhan and Berdan rivers respectively. The area between the two rivers is a relatively flat, alluvial delta at less than 50 m above sea level with slopes varying between 1% and 0.1%. This delta covers about 220,000 ha of land of which about 170,000 are irrigated. The flat landscape is from time to time interrupted by small, isolated hills, and a narrow band of sand dunes running parallel to the coast line, obstructing the natural drainage of rain water into the sea. The dunes are interspaced with lagoons and swampy, poorly drained areas. The largest of these lagoons, Akyatan, is more than 16 km in length and covers about 5000 ha. All excess water from the irrigation project is collected in three main drainage canals reaching the sea or the two main lakes: Akyatan and Tuz Gölü. The major malaria problem in Chukurova is caused by the height of the water-table, which in
Fig. 11. Areas where chloroquine-resistant *Plasmodium falciparum* has been reported
Zones dans lesquelles une résistance de *Plasmodium falciparum* à la chloroquine a été enregistrée
many areas is less than one metre below the surface, and consequently the draining ditches always contain water. Phase III of the Lower Seyhan Project which has not yet been implemented (in 1982) due to financial constraints would involve pumping out the water to the sea, and by itself would relieve many of the drainage problems by lowering the water-table over Chukurova. The surface of the area is 38,506 km². According to the 1980 census, the total population is 3,185,945 inhabitants living in 1,380 localities, of whom about 51% live in urban areas. In addition, about 700,000 seasonal workers increase the total population by 22% and the rural population by 45%. As agriculture is the main activity in the area, migrant workers are found at different seasons, as they usually arrive in waves. The first group arrives about the middle of April and by the end of June-beginning of July they leave Chukurova to return to their places of origin or they go to work in other areas of the country (Antalya or Aydin). The second group arrives in September and leaves for southeast Anatolia by the end of October. Some will stay for a longer period until the end of the agricultural season, while others settle down in Adana attracted by the opportunity of finding permanent jobs in the industrial areas of Chukurova. Socioeconomic studies carried out during 1978-1979 clearly showed an excessive exposure of the poor migrant workers to the risk of malaria, as the man-biting rates indoors and outdoors was several times higher in the tents of migrant workers than in permanent houses. However, housing is not the only socioeconomic factor precipitating the malaria risk, as there are also many other factors like income, occupation, education etc., which play an equally important role. Another important problem is the urbanization of Adana city. This city has 72 districts and is the 4th largest city in Turkey. However, 23 districts are classified as squatter areas, where environmental conditions favour the development and spread of several communicable diseases.

The climate of Chukurova plain is of the Mediterranean type, having a high humidity throughout the year with hot summers and moderate winters. The highest rainfall is in December (120.2 mm) then the rain decreases gradually until it reaches a minimum (about 4.5 mm) in July-August, thereafter it increases from September.

Historically, at the start of the malaria eradication campaign, the number of malaria cases detected in the Adana region was 5,128 in 1958. The attack phase lasted until 1963. From 1961 to 1963, only 25 cases were reported and the whole region was passed into the consolidation phase during which focal spraying was applied only in villages where positive cases occurred. By the mid 1960's, a warning was signalled about the danger entailed in the arrival of infected workers coming annually from southeast Turkey where malaria transmission still persisted. However, by 1970 the number of malaria cases detected in the whole country was very low (1,263 cases) which led the national and international authorities to believe that the disease was totally under control. The organizational structure of the malaria eradication service then became weakened by reduction of not only the financial support, but also the manpower. In fact, during the same year of 1970 the number of cases detected in Chukurova rose from 49 to 149 and this passed unnoticed. Meanwhile, the establishment of irrigation and industrial development projects gave rise to an increase in the population of the Chukurova area. As shown above, the agricultural and industrial expansion demanded an increase in the labour force, either seasonally for cultivating reclaimed land, or permanently for new industrial development. As a result, malaria returned gradually to the area and an epidemic (P. vivax only) hit the area during 1976 and 1977 when the malaria cases recorded were as follows:

<table>
<thead>
<tr>
<th></th>
<th>1976</th>
<th>1977</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chukurova/Amikovasi</td>
<td>30,852</td>
<td>101,867</td>
</tr>
<tr>
<td>Turkey (other areas)</td>
<td>37,320</td>
<td>115,512</td>
</tr>
</tbody>
</table>

A national emergency situation was then declared in the whole country, and intensive control measures were applied [see Onori & Grab, 1980, under (ii),1, above] with the assistance of other countries and international organizations. As a result of these measures, the number of positive cases markedly decreased in 1978 to 70,468, and in 1979 to 18,828. During this period, Turkey experienced administrative problems and a severe economic crisis. Therefore, the impact of control measures was only relative to the epidemic level, but it was later impossible to maintain the downward trend. Despite the efforts deployed by the national authorities, the malaria situation in Chukurova/Amikovasi in recent years is still perturbing as indicated from the number of cases detected during 1980-1982:
With regard to agricultural development of Chukurova, two national organizations are in charge:

- The State Hydraulic Works (DSI) which is responsible for the design, construction, operation and maintenance of irrigation and energy projects (water reservoirs, drainage, irrigation canals, energy plants etc.). It should be noted that the principal period of irrigation is June-August, i.e., the period of lowest rainfall.

- Soil and Water Development (TOPRAKSU) which is responsible for providing technical assistance to farmers for implementing efficient agricultural procedures that would render maximum benefit per unit of cultivated land.

Lassen (loc.cit.) further described the antimalaria measures carried out in the Adana region as follows:

(a) Surveillance and chemoprophylaxis: The general plan of surveillance in Chukurova in 1982 estimated the work output per surveillance agent as follows:

Once a month: 5000 persons to be visited by one agent per month.  
Twice a month: 2500 persons to be visited by one agent per month.

The responsibilities of the surveillance agent are multiple involving: treatment and follow-up of malaria cases, house numbering control, population census, mass chemoprophylaxis where planned and health education. It should be noted that several ethnic groups from the surroundings are represented in Chukurova. In some settlements, the G6PD-deficiency was recorded in a relatively high proportion of the population, a problem which may cause difficulties in the radical treatment of malaria cases with primaquine unless great care is taken.

(b) House spraying: Spraying with malathion at 2 g/m² is carried out twice yearly. The quality of the operation decreased during 1979-1981 due to several factors, amongst which was the reluctance of the population to accept the spraying of their houses.

(c) Larviciding: A variety of saccarovi breeding places exists in Chukurova such as rice fields, irrigation and drainage canals, permanent land depressions, water pools, large man-made burrow-pits, road embankments etc. Irrigation canals normally do not pose an important breeding problem, but sometimes over-flow or leaks through the joints of canaleas or through failures in the system may eventually create pools of standing water. Obstructed irrigation siphons can also create a problem. Two types of larviciding formulations have been used: 1% temephos sand granules and 50% temephos EC, at a rate of 110 g active ingredient/ha. Granules are used where emergent vegetation is present.

(d) Filling: Sanitary filling as a method of larval control is undertaken by Adana Municipality. A large land depression in one of the bands of the Seyhan river is used for garbage disposal. DSI and TOPRAKSU also carry out some filling of important land depressions in the vicinity of main towns, but this activity is limited by the inadequacy of the number of earth moving equipment in both organizations.

(e) Canal maintenance: Climatological and human factors play an important role in the obstruction of canals. DSI has a department responsible for canal maintenance of the irrigation system. Information is available in the department on the different types of emerging vegetation, the speed of growth, the optimal interval between the consecutive silt removal operations and the mechanical output of each engine used for maintenance of the canals (linear metres of canal cleaned per engine per cross-section of the canal). Silt cannot be removed in the rainy season. Vegetation returns in less than two months.

1. Turkish Directorate of State Hydraulic work, of the Ministry of Energy and Natural Resources.
2. Turkish Directorate of Irrigated Agriculture, Ministry of Village Affairs.
(f) Drainage: This is not a routine operation, neither for SDI nor for TOPRAKSU. In the past some land depressions have been drained.

(g) Water pumping: This operation is carried out only during emergency situations in Adana city when flooding occurs.

(h) Water reservoir maintenance: Several natural and man-made reservoirs exist in the area. Very little or no maintenance operations are carried out in natural reservoirs. There are two natural water reservoirs: Akyatan lake and Tuz Gölü as well as land depressions in Bahçe and Karatas. In addition, there are two man-made reservoirs: the agro-energetic project of Adana (DSI), and the equalizing water basin of the same irrigation system. The shores of the man-made lake are properly maintained by DSI, and these do not pose a mosquito problem. The shores are not maintained on a routine basis, neither the bottom of this reservoir which is emptied and filled up every year according to the irrigation needs. The reservoir is emptied at the end of the irrigation season (November) and for a certain period it remains dry except for the river bed (Seyhan river) which continues to run southwardly. The melting of snow and the heavy rains during December-March replenish the main reservoir, but the equalizing reservoir is not filled until April, when SDI opens the gates of the main dam lake to fill the equalizing reservoir completely for the irrigation season. The main problem of this artificial lake is the emergent and horizontal vegetation. Due to the condition of the water bed which consists of mud, it is very difficult for the DSI tractors and bulldozers to operate on it to cut the vegetation and labour force is thus needed. This kind of maintenance was already tried in 1981, but in a few weeks time, the vegetation grew back again to the original level causing the stagnation of large masses of water at sites where horizontal vegetation existed and a very high density of saccarovi larvae was encountered, and subsequently malaria cases in the districts around the lake increased. During 1981, a larviciding programme carried out through the use of a rowing boat provided a satisfactory degree of control, reducing the larval density, and consequently the number of malaria cases decreased.

(i) Space spraying:

- Outdoor space spraying by Swingfog with malathion 400 TF: As indicated by mortality of caged mosquitoes, there was practically no penetration of the fog into houses, even when the doors and windows were left open. It was found that fogging was effective when the Swingfog passed about 1 m from an open window.

- Indoor winter fogging by Swingfog with Neopybuthrin: Although this treatment applied at 15 days intervals during January-February 1982 apparently reduced considerably the build up of saccarovi density in the spring in most areas, this reduction occurred also in untreated areas due to rainfall being only 1/4 of the normal amount during January-April 1982. The dosage used was 50 ml Neopybuthrin/ha, but the coverage was not determined. This technique, however, started to be used in 1982 in those suburbs of Adana where high numbers of malaria cases were detected during the previous transmission season.

- Indoor ULV by Fontan with perimiphos-methyl: Preliminary trials showed that a good kill was obtained in houses treated at a rate of 200 ml of 50% perimiphos methyl/ha, but in open stables no satisfactory kill could be obtained. It should be noted that there has been no systematic reporting of either indoor or outdoor space spraying applications, and likewise epidemiological/entomological assessment was lacking.

Finally, Lassen discussed the development of community participation, PHC and multisectoral cooperation in Turkey as shown under para 3 below.

Giglioli (1979) in an unpublished report to WHO reviewed the history of malaria in Adana plains of Turkey, and described in detail the Seyhan irrigation project which was initiated in 1967. The reclaimed area of the Seyhan project covers about 104 102 ha and in addition 30 000 ha of the adjacent Ceyhan/Aslantas scheme. Ground view of this large project area was too limited to illustrate the sources of the malaria problem. Having had the facility of flying over the area in a military helicopter, Giglioli could illustrate the problems in this project schematically as shown in Fig. 12.1

1. Reproduced by permission of WHO/EURO
Fig. 12. Mosquito breeding sites in the Seyhan project area, Turkey.
report by WHO, the Seyhan project is served by 2200 km of concrete-lined irrigation canals and canalettes with about 3000 road-underpass siphons and many level-drop boxes. Excess water is collected through 490 km of 1-1.5 m wide tertiary canals, 544 km of 2-3 m wide secondary canals leading finally to the sea or the Seyhan river via 412 km of 5-35 m wide primary canals. All these drainage canals are unlined and most of the 1446 km canals built and maintained by DSI contain sufficient water for mosquito breeding throughout the year, except those situated above the 20 m contour north of Tarsus-Misalis highway, which probably dry up between irrigation cycles at the height of the summer. In addition to the above system, there are many kilometres of tile drains and on-farm quaternary, installed by TOPRAKSU and maintained mainly by the farmers. Tile drains of plastic or cement piping are buried 1.5-1.8 m deep every 80-100 m, and help in draining 45 L87 ha, i.e., about 45% of the project area. They are designed to draw off 2 mm per day, and TOPRAKSU and Tekinel et al. (1975) admitted that a spacing of 50 cm was more suitable for local conditions. It was observed that even under the water-logged conditions of January/February, the outlets of tile drains were never occluded by their flow of water and usually half of their lumen was left open. During the hot and dry conditions of the summer, it is likely that these drains are used as cool, damp outside-resting sites by mosquito vectors. This should be investigated in view of the extent of the system.

For allocation of irrigation water, the farmer informs DSI of his intended crop, area, time of planting and water schedules. DSI calculates the exact needs for each section and farmer, allowing for an in-transfer loss of 16-20% in the primary, 5% in the secondary and tertiary canals. Time and volume schedules are then forwarded to the Ditch Runner of DSI who is responsible for measuring the scheduled water to farms in his 1000 ha subarea and reporting the maintenance needs. Therefore, the final responsibility for use and misuse of this elaborate and expensive irrigation system rests on the lowest man, the Ditch Runner, an unfair and unsafe burden. Mobile and effective supervision is desirable and could easily be effected by an agricultural engineer. It is generally accepted that the farmer uses too much water (up to 2-3 times his needs), and that water infringement is not uncommon.

The most important feature of the earlier NWES and the present reorganized service in Turkey is the constant lack of experienced entomologists, hence the lack of longitudinal data on mosquito bionomics on which the control strategy can be based. From the available information, sacharovi is the most important vector in Seyhan, followed to a lesser extent by hyrcanus, while superpictus is thought to be absent from the Adana region at the present time. An. sacharovi has been reported to breed in all water bodies in Seyhan, ranging from fresh to 2% sea water. Its larvae have been recovered from drainage canals, underpass siphons, tail-end field ponds, overirrigated fields and burrow-pits. As Giglioli visited the project area in January-February when no vector breeding occurred, he collected information from colleagues who have visited Seyhan during the mosquito season. This clearly confirmed that the water system, mainly the drainage canals and ancillary bodies of standing water, are contributing to anophelism in the project area as shown in the following:

(a) Irrigation system: The formation of breeding places for sacharovi during March-October was described, and it was concluded that it is possible that the apparently harmless irrigation system is contributing to anophelism in the project area when not in use. Frequent inspections (weekly) would establish if this is so.

(b) Drainage system: One major contributor to anophelism in the project area is the more than 1 446 km of overgrown, earth drainage canals (see Fig. 12). Even if these were maintained at a high standard they could still produce some mosquitoes, but in their grossly overgrown condition involving about 2 m high emergent Cannas and Typha in February, and dense beds of submerged Chara and Potamogeton spp. in summer, they represent ideal breeding places for sacharovi. DSI is responsible for cleaning the canals, mainly by desilting them on a 3-year basis, but in practice this is done every 5-6 years. Maintenance is done by the use of herbicides, drag-lines and hydraulic excavators.

- Herbicides: The use of herbicides by DSI is confined to the cotton off-season (October-December). Due to a shortage of funds, this application is inadequate, for example, in 1978 the allocation covered only 46% of the requirements. The DSI Herbicide unit should be expanded to cope with these responsibilities.
- Mechanical maintenance: The main aim of this operation is periodic removal of silt from the canals, but from the point of view of controlling anopheline breeding, the frequent removal of emergent vegetation and aquatic weeds is much more important. When the silt is removed from the canals, hydraulic excavators create large spoil mounds on one side. These should be joined, levelled and shaped into roads to give access to both sides of the canals for removal of weeds. In the larger canals, the most suitable equipment for this would be hydraulic flail cutters with a long reach, which can be mounted on most large agricultural tractors. Smaller ditches (quaternary drains) would be more efficiently maintained by rotary ditch diggers mounted behind the standard agricultural tractors which exist in the area. Sufficient space should be left on one side of the drain to allow continued maintenance.

The greatest fault in the Seyhan project lies in the drainage system. The best solution would be to line the drainage canals with concrete, as was done in the Pontine marshes, Italy. Although the capital cost seems to be prohibitive, in the long run it would be cheaper than the recurrent expenses of maintenance of the system in addition to the cost of vector control.

(c) Ancillary water bodies: Bodies of water, both natural and byproducts of the Seyhan project are as important sources of breeding as the drainage system. In the haste to develop the area, the landscape has been pockmarked by single and semi-continuous collections of burrow-pits that had been left over from supplying fill for house construction, major roads, farm roads, flood control levees etc., (see Fig. 12). In some places, the field margins were deeply eroded. This occurred where the farmer had released excessive irrigation water into an adjacent roadside borrow-pit, simply by breaking the field margin. This created deep furrows, a few metres long, having depressions suitable for mosquito breeding. The net result is that along man-made elevations, breeding grounds have been created, which should be joined in an orderly manner then connected with the drainage system. Alternatively, spoil from cleaning irrigation canals could be used for filling these pits and other depressions in and around Adana, and later, around villages to reduce breeding in the proximity of settlements. Another obvious defect, especially in the flood plain of Seyhan, and near the last phase of the project (Phase III) was the presence of small and large isolated marshes. These should be connected with the river, or the nearest drainage ditch, so that the standing water can be reduced as much as possible.

(d) Rice fields: These are controlled under the "Rice Paddy Law", which had been established because of the high incidence of malaria in pre-DDT days. This law, enforced by the Rice Commission, imposes that the rice fields under intermittent irrigation be situated at a distance of at least 300 m from the nearest human habitations, and those with continuous irrigation should be situated at least 3 km from habitations. In Selfike, however, little respect for these regulations was evident, but perhaps more important, was the lack of control over the rice area. The Seyhan plan called for not more than 5% of the area to be devoted to rice, but DSI admitted that up to 15% was used for rice, which is even planted on tile-drained land. Although this is obviously a bad practice, DSI had no authority to limit or even withhold water if the farmer wants to misuse it by submerging reclaimed drained land, and consequently flood the drainage system in that area from April to November, a practice which encourages mosquito production.

(e) The poorly drained soil of Phase III: There appeared to be a strong wish to reclaim the boggy lands of Phase III. As cited by Giglioli (in a personal communication) Prof. O. Tekinel, Dean of the Faculty of Agricultural Engineering, Cukurova University, Adana) was of the opinion that the poor drainage of this seaward area, was impeding the drainage of the already reclaimed lands of Phase I & II. He proposed this as one of the reasons for starting Phase III development as soon as possible. This being the case, one hopes that the drainage of Phase III area will be designed to handle much more than the irrigation input, and that all bodies of standing water will be incorporated. Further, it is hoped that the development of the drainage system will precede the irrigation system, in order to gain full benefit from both Phase III, and I & II areas as soon as possible.

Gratz (1987) indicated that in 1984 discussions with irrigation and drainage authorities of Chukurova revealed that there were no plans to improve the drainage system in the area, and to do so was considered excessively costly. It must also be emphasized that such drainage improvements are beyond the responsibility, competence or control of
the malaria service or health services in Turkey. Gratz further added that a new dam and irrigation system is being constructed in the Uria area to the east of Chukurova plain. This area is already endemic for malaria, and will undoubtedly attract many migrant workers. Whether or not the lessons obtained from Chukurova plain will be taken into account remains to be seen.

In Morocco, Prothero (1964) discussed the problem of population movement in relation to malaria eradication. He pointed out that irrigated areas need to be known in detail because of the importance of water in relation to vector breeding, and the attraction of the economic development connected with irrigation on population movement. He advised that very detailed information on irrigated areas was available in the Office of Irrigation of Morocco and use should be made of such information when planning malaria eradication. The types of movements which take place in Morocco may be fitted in the following major categories:

(a) Nomadism: This is the movement of pastoralists in which the whole group of people, men, women and children together with animals, participate. These movements are for the most part determined by the availability of pasture and water for animals. The general seasonal pattern of movements may be the same from year to year but the actual movements are not rigidly defined, as there are very considerable variations in the pattern from one year to another. The variation in patterns of movements results from variation in environmental conditions, particularly the incidence and amount of rainfall.

(b) Labour migration: This involves movement of people who are attracted to work away from home for limited periods of time, principally by the prospect of economic gain. After working for a certain period they return to their home areas. Although they may leave to work again, they are effectively based in their home areas. These may follow a regular pattern (e.g., seasonal or be quite irregular). The movement is made to areas of more advanced economic development (agricultural or industrial), where there is a demand for labour.

(c) Rural exodus: People are attracted for social and economic reasons to leave the country-side to settle in towns, resulting in de-population of rural areas on the one hand and rapid urban growth on the other. In contrast to migrant labour movements, the rural exodus produces a permanent move without periodic return to home areas. This permanent move involves the whole family, whereas labour migration usually involves adult males.

(d) Transhumance: There is a valid distinction between transhumance and nomadism which is important for malaria eradication programmes and for the application of public health measures in general. Transhumant movements are usually in a vertical rather than a horizontal direction, i.e., from the plain to the mountain and vice versa, controlled by seasonal changes in climate. They are regular and not subjected to marked fluctuations from one year to another. The routes that are followed are well defined and are adhered to, and likewise the grazing area used by different groups. These features contrast with those of nomadic pastoralists, besides which there are other important differences. In the case of transhumance, people have permanent dwellings from which their movement takes place and associated with these there is land which is regularly cultivated. The movement of animals to various grazing grounds at different times of the year does not involve the movement of whole families. Only some members of each group move with the animals, and normally there are always some people who remain occupying the permanent settlement. In Morocco, there are two major sub-categories of transhumance:

- Summer transhumance: ("estival") which lasts from May to October and involves movements from the lower-lying valley floors to the higher pastures from which the snow has melted and the grazing is good. Only those who are immediately concerned in the tending of the animals take part in the summer transhumance, and the major part of the population remains in the permanent villages. Transhumance has tended to involve a progressively smaller proportion of the population.

- Winter transhumance: This lasts from November to March and involves movements away from the mountains to the lower altitudes of the plains and plateaux that surround them. A greater proportion of the population may be involved than in summer transhumance. There is a considerable variation in the movement of different groups, depending on the areas in which they are located. Some groups, like the Ben Nguil in
the Moyen Atlas undertake double transhumance, moving upwards in summer and downwards in winter, where their permanent settlements are located. Other groups undertake only summer transhumance and spend the winter in their permanent settlements.

Prothero further reviewed the available information on the extent of each type of the above-mentioned population movements in Morocco and discussed the malaria risks. In his conclusions, he pointed out that while pastoralism (nomadism and transhumance) is progressively declining, other forms of movements (migrant labour and rural exodus) are becoming more important. This trend is likely to lessen the problems of malaria associated with mobility, but the rate at which the changes are taking place is slow. It should not be difficult to deal with the rural exodus. Likewise, migrant labour associated with mineral and industrial developments can be checked upon, but those working in agricultural enterprises will need more specific investigation. Prothero, however, considered that the types of population movements in Morocco were unlikely to present problems for malaria eradication comparable to those to be faced in countries of Africa south of the Sahara. Within the infrastructure being established by the Ministry of Health, it was envisaged that the programme for eradication of malaria will be integrated into the general programme for the development of a country-wide public health service. It should be possible to build up and maintain a body of data on population mobility and on other human factors which are likely to influence malaria eradication. The detailed local knowledge which the "aides sanitaires" are intended to collect should be extremely useful. [A long time has passed since this study was undertaken. It needs to be updated with a view to elucidating the relationship between population movements and the persistence of malaria transmission in certain foci under the present socioeconomic conditions].

One published epidemiological study on one of the water-resources projects in Morocco could be traced. This was reported by Deschliens & Cornu (1975) who visited the area of Hassan Addakhil dam situated on the Ziz river 10 km north of Kasr-es-Souk on the Haut Atlas, at the time of its construction in 1970 and later in 1974 after the dam and its lake and the irrigation network had been functioning. Detailed description of the dam and its lake was given with schematic illustrations presented. Briefly, the maximum capacity of dam lake was estimated to be 380 million cubic metres. The lake through its primary canals (closed or open), secondary and tertiary canals in the lower valley of Tafilalet can irrigate about 4400 km² of land. In 1970, the prevalence of urinary schistosomiasis among schoolchildren at Tafilalet was as high as 10%. With regard to malaria, there were important active foci. P. vivax was the predominant infection encountered, while P. falciparum was rarely found and P. malariae exceptionally recorded. The anopheline fauna was similar to that of the Sahara: sergentii, multicolor and hispaniola. An. labranchiae which is considered the main vector of malaria in Morocco, was exceptionally found in the south of the Haut Atlas.

The observations carried out during 27 May-2 June 1974 showed that:

- The temperature of the water of the lake at the surface was 21°C and the pH 6-6.5, a condition which favours the development of Bulinus snails and mosquito larvae.

- The temperature of the water at the shores of the lake and its creeks was 22-24°C which reflects the effect of the heat of the sun, a condition which favours the growth of vegetation and the development of invertebrate hosts. Nevertheless, the whole surface of the lake and its creeks up to a depth of 4-5 m was devoid of submerged and emergent vegetation. This was not surprising because the lake was newly formed in a rocky structure in an arid zone and has been subjected to changes in the water level.

- Neither mosquito larvae nor snails could be found; only some crustacea including Daphnia and Cyclops were seen.

With regard to the ecological and epidemiological changes in future (10-15 years), the growth of aquatic and shore-line vegetation is to be expected. Likewise, the development of snail intermediate hosts and mosquito larval populations will undoubtedly occur. This will commence in the creeks and valleys of the lake with little depth, where alluvial sediment accumulates, and in particular at sites where herds of animals abound. In the meantime, no human population exists in the area except for some houses remaining since the construction of the dam which are visited casually. There are also some gardens and
palm groves in the vicinity but no snails or mosquito larvae could be found in these sites. In conclusion, with the repopulation of the area especially the lower valleys where new irrigation schemes are envisaged, careful monitoring should be maintained for timely control of snail intermediate hosts and vector larval populations. [No new information could be traced on the situation in this area at the present time].

In Algeria, the construction of the trans-Saharan highway has received much attention in view of its growing economic importance and possible epidemiological implications for countries of north Africa as a result of increasing traffic of vehicles. Emphasis has been made on the risk of establishment of P. falciparum transmission from imported cases originating in African countries south of the Sahara, and the introduction of An. gambiae s.l. through the speedy traffic as shown below. It is necessary first to give a résumé of the available knowledge on the northernmost limits of distribution of the An. gambiae complex in West Africa.1 Cox (1973) gave the northernmost records of arabiensis up to Boutilimit in Mauritania (17°03'N latitude 14°35'W longitude); arabiensis and gambiae s.s. at Bafoulabe in Mali (14°04'N, 10°30'W); and both species at Ayourou in Niger (14°44'N, 0°56'E). Previously Hamon et al. (1966) recorded on their maps both species as far as 17°00'N, 7°00'E in Niger. In northern Chad, Rioux (1960) recorded in September 1958 and August 1959 An. gambiae s.l. in palm groves of Faya-Largeau and as far as the Tibesti Massif in the extreme north (17°00'-22°00'N). More recently, Stafford Smith (1981) carried out a mosquito survey from southern Niger (13°06'N) to the north (19°06'N) including the border area of Algeria. He found specimens identified cytogenetically as arabiensis 5 km north of Agadez and this represented the northernmost record (17°00'N) of this species in Niger. Stafford Smith pointed to the implications of road construction involving excavations that form large burrow-plts which become filled with water during the rainy season forming small lakes. This can greatly facilitate the spread of Afrotropical species to the north. Moreover, with mineral exploitatons, new settlements will be established in the north, and with the increased traffic, arabiensis may get established in potential breeding places in the north. Also, it is expected that the use of air-conditioned trucks and containerized vehicles will shorten the travel time, and with the increased movement at night, there will be a danger of long distance transportation of vector species through the Sahara to the southern oases of Algeria.

Ramsdale & Zulueta (1983) who described the distribution of local anopheline species in northern and southern Algeria, discussed the implications of the construction of the trans-Saharan highway - see Tables 13 a & b and Fig. 2 under 2.5 above. Their discussion examined the possibilities of establishing malaria transmission from imported cases originating in West Africa through local anopheline vectors or the exotic vectors An. gambiae s.s. and An. arabiensis. P. vivax which is still encountered in the Mediterranean Basin is absent from, or extremely rare in, West Africa. P. falciparum is most likely to form the bulk of malaria imported into Algeria as it is the predominant species in West Africa where the levels of temperature permit its transmission throughout the year. It is known that the threshold of temperature for the sporogonic cycle of P. falciparum is 19°C, below which the development of the parasite is indefinitely retarded. In Tamanrasset, south of Algeria, the mean temperature falls below this threshold during 5 months each year. This unfavourable period is shorter at lower altitudes, lasting only 3 months at Aoulef, but becomes progressively longer with increasing latitude. It extends to 5 months at Golea, 7 months at Lagouat and Algiers and longer in the highlands of the Atlas. Additionally, an important limiting factor that may also explain the absence of autochthonous P. falciparum from the Mediterranean Basin, being the marked refractoriness of members of the An. maculipennis complex, including labranchiae to exotic strains of P. falciparum, as was demonstrated experimentally, citing several authors2. The situation in the southern oases of Algeria where outbreaks of P. falciparum malaria transmitted by local vectors were reported previously, citing several workers including Lefèvre-Hitier (1968) [see under (ii), 1 above]. The situation in northern Algeria is quite different where labranchiae is the vector. Any increased movement into and across the desert will inevitably affect the vulnerability of many oases, particularly those of Hoggar. Until problems of vector identification are resolved, the degree of receptivity of these oases will remain a matter of speculation.

1. For more details see PART I, SECTION III (A) WEST AFRICA in Document VBC/85.1-MAP/85.1, pp. 11-15.
2. See VOL. I under 2.8.2 (ii), pp. 158-161, in document VBC/88.5-MAP/88.2.
The most pressing need is for clarification of the taxonomic status of various populations of *sergentii* s.l. (see the suggestion of the authors under (i), 2.5 above). The type form, *sergentii* *sergentii* can be a good vector of *P. falciparum*.

Ransdale & Zulueta (loc.cit.) further suggested that even after the completion of the trans-Saharan highway, the long journey across the desert will still be extremely hazardous for mosquitoes, and the risk of importation of *arabiensis* and/or *gambiae* s.s. into the Mediterranean Basin by road may not exceed that of importation by air. Examples were given of the historic importation of *gambiae* s.l. into Brazil during the 1930's and Egypt during the 1940's (see below). However, successful establishment of introduced species depends on the presence of suitable conditions locally. It is unlikely that *arabiensis* and *gambiae* s.s. would find such conditions in northern Algeria, though they may be able to develop one or more generations during the summer. The inability of *arabiensis* and *gambiae* s.s. to extend their range into Hoggar illustrates the formidable nature of the desert barrier. The journey from Agades to Tamanrasset covering a distance of 970 km currently takes three or more days of travel across hot arid desert, with the possibility of travelling at night being severely limited by the ill-defined nature of much of the route. When the highway is opened it will be possible to complete this journey in less than 24 hours, avoiding the worst of the heat by travelling during the night. If mosquitoes are periodically able to extend their range north from Agades through the seasonally swampy Azaouak valley, the distance they must be transported over and the time necessary for the journey to Hoggar will be comparatively less. An increase in the volume of traffic and the use of insulated vehicles and air-conditioned cabs after the completion of the highway must make the introduction of *arabiensis* and/or *gambiae* s.s. into Hoggar probable, even inevitable. If they are able to establish themselves in Hoggar, their further spread into other southern oases may be rapid. Because of the salinity of surface water, it is improbable that these two vectors could colonize many of the northern oases at the present time. However, future development could change the situation as seen at Zefana, where a new agricultural complex was established in 1948 with water drawn from a deep reservoir under the Sahara. Studies carried out three years later showed that this new oasis was already populated by seven mosquito species. A deep underground reservoir has also been tapped at El Golea, formerly a brackish water but now a flourishing oasis. *An. sergentii* s.l. has been found breeding in fresh water at El Golea.

Chauvet, Hassani & Izri (1985) described the trans-Saharan highway and discussed its implications for Algeria and countries of the Maghreb. Twenty years ago the countries bordering the Sahara decided to create a trans-Saharan north-south route for increasing and intensifying the exchange of their commercial and human resources. The countries which were directly involved: Algeria, Tunisia, Niger and Mali formed a committee for preparing the plan of this project at a continental level. At the Algerian initiatives, the work was started in 1971. In 1979, the distance between Lagouat-Tamanrasset (1600 km) was terminated with the financial assistance of the United Nations Development Programme (UNDP). Alger could be reached from Tamanrasset in not more than a one-day journey by car at a speed of 80-100 km on the newly paved tarmac road. Two lateral routes were constructed: one from Ghardala to reach southern Tunisia via Ouargla and Touggourt, and the other connects Ouargla and Ghadames. To the south of Tamanrasset, the work continues, and at 70 km from this town the route branches into two: one reaches Gao in Mali (at 100 km) via Tin-Zaouaten and Kidal, and the other reaches Agades in Niger (900 km) via In Guezzam and Arlit. The importance of this undertaking comes from the numerous socioeconomic benefits arising from transportation of goods, people and animals, development of small and medium industrial projects, exploitation of minerals, tourism and the hotel industry. The route will also permit Niger and certain provinces in Nigeria to have a new, easy, rapid and less expensive access to the Mediterranean for the European market. The trans-Saharan traffic which was at a level of 5000 tons (t)/year in 1968 has now reached 250 000 t/year, corresponding to 50 000 trucks/year (about 150 trucks/day). It has also been estimated that about 4000 persons are transported daily on this route. This bright socioeconomic prospect is, however, clouded by the risk of trans-Saharan exchange of communicable diseases. Further, the authors discussed the risks of circulation of malaria parasites and the vectors.

Despite the continuous importation of *P. falciparum* from the Sudan-Sahel zone, not a single case of this parasite has been found north of the Mediterranean. The same reason shown above regarding the incompatibility of *labranchiae* to tropical strains of *P.
falciparum was suggested. The authors further assumed that the local vectors of the Sahara may also be inefficient in transmitting tropical strains of P. falciparum. Nevertheless, this assumption should be met with caution because of the past severe epidemics of falciparum malaria that broke out in Tassili N'Ajers (citing Brousses, 1930 and Léfevre-Witté, 1968), where sergentii and multicolor were present. Such assumptions should be verified experimentally since anopheles populations may consist of strains differing in their vectorial efficiency in the same way the plasmodial strains differ in their infective capacity. The same suggestion was made calling for the need to clarify the taxonomic status of sergentii s.l. (see 2.5 above).

- Circulation of the vectors: Examples exist indicating that traffic circulation led to rapid colonization of new water sites in newly established Saharan oases in Algeria, by sergentii and multicolor which are well adapted to such environment, (citing Benabadji & Larrouy, 1969). It is possible that the two species will progress south of the Sahel, but this will not change anything because malaria transmission by An. gambiae s.l. is so dense that the role of those two less efficient vectors is negligible. At worst their presence might prolong the transmission season because they are perfectly adapted to the dry climate environment. On the other hand, the greatest risk lies in the extension of An. gambiae s.l. to the north. Members of this complex exist in the Sahel zone up to 16-17°N covering Mauritania, Mali, Niger and Chad. It has also been recorded from Agades on the Niger branch of the trans-Saharan highway. More perturbing is the record of An. gambiae s.l. from an isolated station on the northern slopes of Tibesti near the Libyan border (citing Rioux, 1960 – see above). This author suggested that the presence of An. gambiae s.l. at this station represented a relict fauna rather than a new introduction. Chauvet, Hassani & Izri (loc.cit.) pointed to a previous record of An. gambiae s.l. from Ghad in Tanezzouf valley in southern Fezzan province, Libya close to the Algerian-Libyan border, 100 km as the crow flies from Djemet, Algeria. [The authors did not give the reference of this record. However, the old record of An. gambiae s.l. south of Fezzan could not be confirmed – see under (ii) 1 above]. Regarding An. funestus, the second major vector in tropical Africa, there is no danger of its introduction in the north, since it has special ecological needs by breeding strictly in freshwater and is very sensitive to water salinity which prevails in the north.

For prevention and control, the authors suggested the following measures:

(a) Amplify the knowledge of the seasonality of malaria transmission in the Maghreb.
(b) Intensifying control measures in known foci using different anti-vector measures as well as treatment of cases.
(c) Using all possible means in the Maghreb to prevent the introduction and establishment of exotic strains of P. falciparum and An. gambiae s.l.
(d) In the Sahel, rigorous attempts should be made for elimination of malaria transmission and for treatment of cases particularly migrant populations at frontier areas before they proceed north.

These measures would need an adequate infrastructure served by well-trained and motivated personnel. Equally important is the establishment of an intra-African scientific and operational cooperation.

In their assessment of the malaria situation in the Algerian Sahara, Benzerroug & Jansens (1985) [see (ii), 1 above], provided information on the movement of the population and vehicles across the frontier posts with Mali and Niger. The number of persons entering Algeria through the southern frontiers has considerably increased: from 3530 persons in 1978 (836 nationals and 1423 foreigners) to 12 434 in 1984 (3003 nationals and 9426 foreigners). There was a parallel increase in the number of vehicles entering through the same posts: from 1110 in 1978 to 3413 in 1984. These data reflect the amount of movement of the population across the southern border as a result of the construction of the trans-Saharan highway which extends to 5929 km to connect Lagos with Algiers.

Bruce-Chwatt (1986) also re-emphasized the risk of reintroduction of malaria into countries of North Africa through the trans-Saharan highway. Although not yet completed, this all-weather highway has a hard surface of some 3400 km, from Algiers, through Laghouat, El Golea, In Salah, Tamanrasset, In Guezzam, and Agades (see Fig. 2). Further south, it branches westwards to Birnin Konni and Niamey (in Niger) and southwards from Zinder (in Niger) to Kano and Lagos (in Nigeria). The western and southern junctions from...
Agades are not yet finished, but the latter is motorable during most of the year. The Saharan plateau measures about 3.5 million m². Its topography varies from rocky wasteland (known locally as hammada), through an intermediate zone of stone and gravel (serir), to the loose and mainly sandy area with drifting dunes (the erg). The highway has been built at altitudes varying between 300 and 600 m, except at the Hoggar highland which rises to 3000 m where the road runs at 1400 m. The climate varies with latitude and altitude. The temperature ranges from 50° C at noon in summer to below 0° C at night in winter, and the humidity is very low. Rainfall is practically nil, but in some parts of the desert sudden storms erupt and may create raging torrents in the usually dry valley. In these arid areas, subsurface water may accumulate in low-lying sites and form saline pools. Except in isolated small or medium oases, the human population is scarce and mostly formed of nomadic tribes, who have been greatly affected by recent droughts. Most of the oil and mineral industries are in the northeastern parts of the Sahara, away from the highway. The growing economic importance of the trans-Saharan highway is reflected from the spectacular rise in the number of vehicles crossing road-posts at the borders of Algeria with southern countries of West Africa. Of 410 malaria cases recorded in Algeria over the past few years, 70% were caused by P. falciparum. A traveller from Tanzania with chloroquine-resistant P. falciparum serves as a reminder of the potential risk of imported malaria from Africa south of the Sahara. [see Benzerroug, 1985, under (ii), 1 above]. Epidemics of P. vivax have occurred in Algeria in the past, and some sporadic cases of P. falciparum have been common. Of the malaria vectors in Algeria, labranchiae is the most important acting as the main vector in coastal areas and the northern zone of the Sahara. Some workers believe that imported tropical strains of P. falciparum are unlikely to cause resurgence of malaria because of the doubtful ability of labranchiae to transmit this infection. An. sergentii is also an important vector in the oases, while multicolor remains a suspected vector in these oases. The greatest danger is that the two notorious tropical vectors An. gambiae s.s. and An. arabiensis would establish themselves in Algeria along the Saharan Highway. The formidable climatic barriers would militate against their establishment in the northern part of the Sahara, but the southern oases of Hoggar, Tidikelt and Tassili would be vulnerable to invasion by these highly adaptable and robust vectors. Air-conditioned vehicles could provide long-distance transport of these two vectors. Additionally, the increase in water supply from deep reservoirs in some new agricultural and industrial projects may contribute to permanent colonization by the two species. Bruce-Chwatt also reminded that the invasions of Brazil and Egypt by An. gambiae s.l. in the 1940’s and the recent transporation of infected tropical vectors by aircraft to airports in Europe should serve as warnings, calling for greater vigilance and effective preventive measures. Although the implications of the trans-Saharan highway were discussed briefly at the Coordination Meeting on the Prevention of the Reintroduction of Malaria in the countries of the western Mediterranean, Erice, Italy, 1979 (WHO, 1979b), [see SECTION I under 1.2.2 in document VBC/90.1-MAL/90.1] more decisive action is needed since several water impoundment projects are being proposed to increase rice production in many countries of North Africa.

In Tunisia, Wernsdorfer (1973) in his unpublished report recalls that towards the end of 1970 a small-scale larviciding trial with temephos 500 EC was conducted in the area of Cap Bon barrage in the Nabeul region. The larvicide was applied at a rate of 75 ml of the concentrate per hectare at fortnightly intervals. As the results were promising, it was decided to apply this larvicide on a large scale, particularly in the foci where sergentii was present. In 1971, the zone of the Bizerte dam and Nabeul region were treated with a dose of 75 ml temephos/hectare every fortnight during May-October 1971. In foci of transmission that persisted in Gafsa and Sfax regions the same temephos treatment was applied during April-November 1971. It was realized that this dosage and frequency was insufficient. Therefore, the dosage was increased to 125 ml temephos/hectare. In 1972, three larviciding squads worked in the zone of consolidation phase: one for treatment of the areas of Bizerte and Nabeul dams fortnightly from April to October, and the other two for foci of transmission in Kairouan and Sfax from March to the end of November. The dosage applied was 250 ml temephos/hectare. In the southern zone, two squads worked in three regions of former foci: Gafsa, Gabès and Médenine, from April to the end of November 1972, applying temephos at 250 ml/hectare weekly. It was demonstrated that this treatment gave complete control of sergentii larvae when coverage was adequate.

In Libya, from recent observations by Ramsdale (1989 - in press) (also in personal communication, 1987), settlement and cultivation in Fezzan (see Fig. 3) are restricted to places where subsoil water can be tapped. Traditional irrigation systems in Fezzan depend
on water drawn by means of an animal-driven 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 breeding sites for sergentii and/or multicolor. The introduction of power driven water pumps some 20-25 years ago allowed lifting increasingly large volumes of water and cultivation of larger plots. Lowering of the water table in the Wadis of Elba and El Adjal made it necessary to substitute the wells by deep closed bores. Water is now pumped into straight sided concrete tanks from which it is distributed through open channels or more often through pipes to sprinklers which save a lot of water. Even where open channels and flood irrigation are still practised, the depressed water table and absorbent sandy soil ensure quick absorption of residual surface water. The only standing surface water in the oases of these wadis is now associated with sewage, hence unsuitable for anopheline breeding. Thus, in an area which includes Sebha, Murzuk and Ubari there is no water surface that can support the development of anopheline larvae. At the same time, sergentii and/or multicolor were still breeding in abundance in other oases, where different aquifers are used as in Hon, Brak, Edri, Aliwanat (Serdeles), and Ghat. In addition to the aquifers mentioned above, reserves of water capable of sustaining a much larger human population underlie much of the Sahara. Large scale exploitation of these reserves has been very limited. This can profoundly affect anopheline prevalence.

In Egypt, the construction of the Aswan High Dam served as a reminder for reinforcing the measures to prevent the reinvasion of *An. gambiae* s.l. from north of Sudan. The history of the northward spread of *An. gambiae* s.l. was shown in Part I. It is more convenient to recapitulate this information here with some additional details.

It is well known that *An. gambiae* s.l., a typical anopheline species of the Afrotropical or the Ethiopian Zoogeographical Region, extended its distribution to the north causing devastating epidemics in Egypt in the early 1940's which necessitated an extensive campaign for its eradication as was thoroughly reported by Shousha (1948). From this report, when a malaria epidemic, associated with *An. gambiae* s.l., broke out in the Egyptian Nubia in May 1942 an entomological survey was carried out to determine the extent of the spread of this exotic species into Egypt. It was soon discovered in several northern localities, up to Assuit city in September and further in November in a small isolated focus in Manfalut, a town situated 25 km north of Assuit, but this focus was dealt with immediately. Thus, the northern limit of *An. gambiae* s.l. was considered to be south of Assuit, a stretch about 850 km along the course of the Nile Valley from Bailana near the Sudan border, covering an area of 4270 km², hitherto representing a narrow cultivated strip of land in the flood plain of the Nile, inhabited by 3 million people. A study of the climatic conditions showed that *An. gambiae* s.l. had only three months, September to November, when it could proliferate in Upper Egypt, but the remaining part of the year represented a difficult period for this species. At the beginning of the initial campaign, which was started in 1942, vector control measures and treatment of malaria cases were gravely hampered by the inadequacy of transport, Paris green and antimalarial drugs due to war conditions.

Shousha (loc.cit.) further showed that in July 1944 the Gambiae-Eradication Service was established, undertaking the control activities as a military operation and following the same techniques and organization as those utilized for extermination of *An. gambiae* s.l. from Brazil after it had invaded the northern part of that country, as described by Soper & Wilson (1943). Complete eradication of *An. gambiae* from Egypt was

2. From Halawani & Shawarby (1957), the persons who organized and participated in this initial campaign were: the late Dr M. Khalil, Dr A. Lutfi, Dr A. Halawani, and Dr A. Shawarby.
3. As acknowledged by Shousha, the Rockefeller Foundation delegated the same experts who had organized the gambiae eradication campaign in Brazil, to work in Egypt. The advice and criticism of Dr F.L. Soper who visited the gambiae-infested area several times, were greatly appreciated. Dr J.A. Kerr became the Director of the Gambiae-Eradication Service and Dr D.B. Wilson became the Field Director in 1944.

1. FROM HALAWANI & SHAWARBY (1957), THE PERSONS WHO ORGANIZED AND PARTICIPATED IN THIS INITIAL CAMPAIGN WERE: THE LATE DR M. KHALIL, DR A. LUTFI, DR A. HALAWANI, AND DR A. SHAWARBY.
firmly established after suspending all control operations during the most favourable period, September-November 1945. In his discussion, Shousha cited the observations of Lewis (1944) made during 1942-1943, showing that An. gambiae s.l. in the Wadi Halfa area of northern Sudan bordering on Egypt, fluctuated seasonally and disappeared in winter months and that the source of its replenishment in Wadi Halfa was the 2nd cataract of the Nile where large breeding pools existed throughout the winter months. Shousha therefore suggested that the northward spread of An. gambiae s.l. may have invaded Upper Egypt prior to 1942, and gave the history of severe malaria epidemics causing large numbers of deaths. No anopheline collections were made at that time but these episodes indicated that An. gambiae s.l. was probably the responsible vector rather than the local vector, An. pharoensis. To conclude, he stated: "But whether or not gambiae ever invaded Egypt before 1942 is rather beside the point. It did so then, and it can do so again, unless adequate protective measures are put into force." He further expressed appreciation of the anti-gambiae measures applied with complete success by the Sudan Medical Service in the area of Wadi Halfa extending to 58 km from the border to the 2nd cataract.

Regarding the malaria situation, Shousha explained that during the difficult year of 1942, it was found that the number of malaria cases notified to the public health offices did not agree with the severity of the epidemic. An estimated incidence of malaria deaths was calculated on the basis of attributing the increased number of deaths in 1942 over 1941 as due to malaria in the infected area which covered the narrow cultivated strip of land in the flood-plain of the Nile, with a population of 3 million people. The death rate due to malaria was estimated as 10% of the cases of 1942 (63 000). In 1943, there was a better detection of early cases and a more liberal distribution of antimalarial drugs, which had an effect in reducing the death rate to 5% of 76 000 cases estimated for 1943. In 1944, the therapeutic service was established and both new cases and relapses were notified. Subsequently, the number of cases was drastically reduced as a result of the eradication campaign as shown in the following:

<table>
<thead>
<tr>
<th>Cases</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New</td>
</tr>
<tr>
<td>1944</td>
<td>32 823</td>
</tr>
<tr>
<td>1945</td>
<td>28</td>
</tr>
<tr>
<td>1946</td>
<td>59</td>
</tr>
</tbody>
</table>

The epidemic caused by the gambiae invasion caused great economic losses in the infested area in Upper Egypt as shown by Halawani & Sharwaby (1957). For example, the Kom Ombo agricultural company, which cultivated an area of about 30 000 acres in Aswan province, was estimated at L.E. 500 000 as a result of a 40% reduction in the labour force during 1943-1944 due to malaria morbidity. The number of deaths of about 12 000 shown by Shousha (1948) was an estimate that fell far short of the true figure, if the secret burials could be added.

Lewis (1949) described the measures applied to exterminate An. gambiae s.l. from the Wadi Halfa area during 1945-1946 in support of the gambiae-eradication campaign in Egypt, adopting the same techniques applied earlier in Brazil. In this report, Lewis (loc.cit.) discussed the northward spread of An. gambiae s.l. into Egypt and excluded a suggestion that this may have been associated with air transport from Central and West Africa, recalling that An. gambiae s.l. occurred in the Wadi Halfa area for many years and it may have "occurred in, or visited the old Aswan Reservoir area, which lies mainly in the tropics, for a long period", citing Lewis, (1944). After providing the proof of An. gambiae s.l. extermination from the Wadi Halfa area by 1946, Lewis (1949) made several recommendations for maintaining the area as a barrier to prevent An. gambiae s.l. spreading into Egypt. Of these, the need for DDT residual spraying of trains coming to Wadi Halfa from the south, in addition to pyrethrum space spraying before their arrival, was emphasized. Noting a previous report on 3-year insect collections from airplanes at Khartoum whereby 16 anophelines were found, of which two were An. gambiae s.l., he proposed the spraying of aircraft at Wadi Halfa and at southern aerodromes.

1. The narrow cultivated strip of Nubia south of Aswan was inundated by the lake of High Dam, and the flood-plain north of Aswan has been transformed into a perennial irrigation system.
Lewis (1956) referring to the northward spread of An. gambiae s.l. in a stretch of about 850 km into Egypt as defined by Shousha (1948), pointed out that this Ethiopian species reached a point 600 km inside the Palearctic Region. Until 1942, its northern limit probably occurred between Saras [about 60 km south of Wadi Halfa — a stretch which has now been inundated by Lake Nasser] and the Tropic of Cancer which traverses the southern part of the old Aswan Reservoir. In this area An. gambiae s.l. apparently could survive relatively cold winters in certain places with long lasting pools and its distribution fluctuated from season to season and perhaps from year to year.

During September—October 1950 a few larvae of An. gambiae s.l. were detected at Abu Simbel and Ballana near the border with Sudan. Through measures applied by the Egyptian Ministry of Health, this limited invasion was dealt with promptly by DDT house spraying and larviciding in all localities of the Egyptian Nubia. Subsequent searches were all negative for An. gambiae s.l. (Zahar, unpublished observations, 1951). On the Sudan side of the border, Lewis (1956) indicated that An. gambiae s.l. did not reappear in the area of Wadi Halfa under control until December of the same year when a few of its larvae were detected in Abdir locality, a short distance south of Wadi Halfa town. This was thought to be either due to failure of control to cover the breeding place or to spread from the south possibly by one female transported by a train during that year of unusually heavy rainfall. Larviciding with DDT in oil was immediately applied as from January 1951 in a stretch extending 80 km south of the border as was suggested by the Egyptian authorities.

With the construction of the Aswan High Dam in Upper Egypt, Fig. 131, and the gradual formation of its lake, (known as Lake Nasser in Egypt and Lake Nubia in Sudan) extending about 500 km to the south including 150 km into Sudan and covering about 6000 km², great ecological changes occurred. Apart from faunistic, floristic and physical changes, all localities of the Egyptian Nubia were inundated and their populations resettled north of Aswan but Abu Simbel was saved by re-establishment at a higher level. Some localities in north Sudan were also inundated, notably the old Wadi Halfa and environs, the population of which was resettled in Khashum El Girba in Kassala province while other localities awaited inundation when the lake was expected to reach its target level of 183 m in 1974. New Wadi Halfa town was re-established south of the old site on the eastern bank of the lake and remained connected with Aswan, Egypt by passenger and cargo boat services sailing from a small port established 3 km from the town, passing through the newly established Abu Simbel locality. The new Wadi Halfa town remained connected with Khartoum by railroad and with the northern province of Sudan by road.

Health hazards arising from the lake received attention from both the Egyptian and Sudanese health authorities, particularly with respect to the potential risk of re-invasion of An. gambiae s.l., the spread of malaria and infestation of schistosomiasis. Several surveys have been undertaken by Egypt and Sudan in the lake area giving special attention to the border area.

In a review of the hazards of re-invasion of An. gambiae s.l. into Egypt arising from the construction of the high dam and formation of Lake Nassar, Shawarby, Mahdi & Kolta (1967) gave the northern limit of An. gambiae s.l. in northern Sudan as Kweka, 193 km south of old Wadi Halfa, citing an unpublished report by Gad on a survey conducted during 1954—1955. At the same time joint teams were organized to control malaria by DDT house spraying and mass drug administration in the area between Halfa and Dongola. In February 1966 a joint committee of the Ministries of Health of Sudan and Egypt met in Khartoum to review the anti-gambiae measures conducted by both countries. At that time the lake had already flooded Saras and its southernmost end was expected to reach Dal, (about 150 km south of Halfa). Thus, intensification of surveys and control measures by larviciding and house spraying in the area between Dal and Abu Fatma (see distances below) and the application of other protective measures were recommended in the hope that An. gambiae s.l. would be eradicated from this area before 1970.

In April 1970 an entomological/parasitological survey was conducted covering the newly established Halfa town (replacing old Wadi Halfa that was inundated) and several localities in a stretch of about 160 km to the south including Dal, as reported on by

2. Simov referred to later as Halfa.
Zahar (1970). These localities were awaiting inundation and in the interim period were covered by DDT house spraying and larviciding. Intensive adult and larval surveys showed a gambiæ-free area extending from Halfa and its port to Akasha, 140 km south, Fig. 141, where abundant culicines were encountered. *An. gambiæ* s.l. was first encountered as larvae (0.5–1.0/10 dips) and as adults resting indoors (0.4–1.0 females/room) at Dal, Sarkamato and Farka. Dal was situated on the west bank of the Nile, about 150 km south of Halfa and this was considered as the northernmost limit of *An. gambiæ* s.l. under the conditions prevailing during the survey. Sarkamato and Farka are situated on the east bank nearly opposite Dal but a little to the south. In this area the Nile at the time of the survey was still narrow and fast flowing with cataracts among basaltic rocks. Inundation which started in 1967 did not much affect these localities but they were awaiting their turn. Many pools were seen in this area which reach a maximum during the flood time but they were at a minimum during the survey. Probably climatic conditions of the dry season during which the survey was carried out were adverse for *An. gambiæ* s.l. longevity and contributed to the low density encountered (temperature 25–35°C & RH 8–35%).

On the malaria situation, the hospital records in Halfa in 1969 showed 10 clinically diagnosed malaria cases among out-patients and 10 microscopically diagnosed cases among in-patients. These were probably imported cases from the endemic areas of Sudan. The dispensary at Farka in the area where *An. gambiæ* s.l. was encountered, clinically diagnosed 105 cases of malaria among 9142 attendants in 1969; 57% of these cases were diagnosed from October–December. None of 1864 blood slides collected during the survey representing about 15% of the total population of seven localities (4 *gambiæ*-free and 3 *gambiæ*-infested), was positive for malaria and some doubts were raised about the quality of microscopical examination. Recommendations were made for reorganizing and improving the larviciding and spraying operations and for testing

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1. Reproduced from the report of Gillies (1972) by permission of WHO/EMRO, (with some modifications to the original map drawn by Dr Mustafa Akood, Entomologist, Antimalaria programmes, Sudan).
Fig. 14. Area surveyed during 1970 and 1971 in the Northern Province, Sudan.

**LAKE NUBIA**

**SCALE:** 1 : 500,000

**COMPiled BY:** MUSTAFA AKOOD 1971

(Figures in parentheses are distances in km along the river south of Wadi Halfa)

- Localities with Angambino c.l.

---

**OLD HALFA (inundated)**

**HARBOUR**

WADI HALFA Town

\[ 21^\circ,46' + \]

\[ 21^\circ,30' + \]

\[ 21^\circ,15' + \]

\[ 31^\circ,06' + \]

\[ 31^\circ,15' + \]
larvivorous fish in permanent pools. Surveys during the favourable season and susceptibility testing of An. gambiae s.l. to DDT were suggested. It was stressed that both Sudan and Egypt should maintain their areas of the lake disease-free on a long-term basis as opposed to temporary short-term measures. As an interim measure, short-term plans should be developed to deal with the changing situation as the lake level rises and likewise, long-term plans should be developed for permanent control when the level stabilizes.

Gillies (1971) reported the results of his observations as a WHO Consultant in the lake area in Egypt and Sudan during October-December 1971. From his review of previous work in northern Sudan, surveys made later confirmed the findings of Zahar (1970) that the northern limit of An. gambiae s.l. was Dal (about 150 km south of Halfa). Also 3767 blood slides collected in July from localities between Dal and Abu Fatma (350 km south of Halfa) were all negative. From this Gillies inferred that little transmission seemed to have occurred in this area despite the presence of An. gambiae s.l. In fact there was little malaria in recent years in Dongola, a populous centre 80 km south of Abu Fatma. However, in the few months preceding his visit, there was a marked resurgence of malaria in the area as signified by the number of microscopically diagnosed cases at the Dongola hospital which reached several hundred per month. This suggested that there was considerable risk of malaria spreading north again unless it could be contained by active control. Further, susceptibility tests made in July 1970 at Kweka (212 km south of Halfa) showed that An. gambiae s.l. was resistant to dieldrin but susceptible to DDT. Gillies warned that this situation could change and reserve stocks of alternative insecticides should be maintained for replacement of DDT. Gillies’ observations in northern Sudan were mainly directed to Halfa and the localities south of it, up to Akasha, at 140 km. At Halfa port only culicines were breeding moderately in covered tanks of a floating wharf. Also, only culicines were found at some localities to the south up to Akasha. From Senna (80 km south of Halfa) to Duwishat (92 km) conditions were considered unfavourable for An. gambiae s.l. breeding where the Nile was transformed into a flooded valley but from Sarjia (127 km) to the upper part of Milk El Nassir (118 km) was the furthest north that could be colonized by a natural spread of An. gambiae s.l. or by its transport over short distances. Thus the northern limit of An. gambiae s.l. according to the previous records, remained at Dal. In his conclusions and recommendations, Gillies underlined that risk of introduction of An. gambiae s.l. into Egypt remains forever. The key links in the chain of events are: firstly, the proliferation of An. gambiae s.l. in the endemic zone of northern Sudan and its spread to the lake ports; secondly its transport by lake steamers to the high dam area in Aswan; thirdly the establishment of breeding populations at this site and later in irrigated areas to the north. Further development along the lake shores could facilitate such transport by providing intermediate breeding populations but the High Dam complex would still be the key port of entry of the species into Egypt. Therefore, all structures of the High Dam complex should be sprayed with DDT twice annually. In the endemic northern part of Sudan, the source of An. gambiae s.l. invasion is most likely to originate from a ribbon of about 230 km of farmland and river valley between Akasha and Abu Fatma Fig. 15. The remoteness of the area, the difficulty of its terrain and the poor communications make regular supervision by senior staff rather difficult. Nevertheless, it should be possible with the available means to keep the population of An. gambiae s.l. at a low level to prevent its northward spread by active and passive routes. The planned two rounds of DDT house spraying annually were endorsed and larviciding with temephos was supported, provided that its efficacy under local conditions is ascertained by a trial. Gillies further pointed out that the long-term risks are difficult to assess but large scale development along the lake shores and associated communications would pose problems of establishment of An. gambiae s.l. and its transportation to Upper Egypt. Close involvement of health authorities from the inception of such development schemes is essential with the An. gambiae s.l. problem one of their major concerns.

An agreement was formulated in 1972 and signed by the Governments of Egypt and Sudan for “Health and Medical Cooperation”. As part of this agreement, the two Governments agreed to cooperate in undertaking measures for eradicating An. gambiae s.l. from the lake area up to Abu Fatma, the details of which were given in a separate protocol. Protective measures need to be intensified at the High Dam complex in Aswan, Abu Simbel and Halfa

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1. Reproduced from the report of Zahar (1970) by permission of WHO/EMRO.
Fig. 15 Map of the Northern Province, SUDAN

SWADI HALFA
Town (km 3)

DOLGO 275 km.

ABU FATMA 350 km.

DONKOLA

KARIMAH

ATBARA
including dissection of riverine transport operating between the two countries, as well as dissection of trains before reaching Halfa. The measures to be continued in Aswan Governorate were also described. In northern Sudan, survey and control operations by larviciding and house spraying should continue in the area between Halfa and Dal. Surveys and periodical larviciding of all breeding places in the area between Dal and Abu Fatma should be continued, besides which house spraying is to be applied using an insecticide to be agreed upon by the two Governments. Positive places detected during adult or larval surveys should be immediately dealt with. The two Governments are to undertake measures to keep the area extending from Aswan to Abu Fatma free from malaria by active case detection and radical treatment of positive cases. Exchange of reports on survey work, surveillance and vector control operations should be made monthly. In addition a joint team is to survey the lake shores twice a year: once in April–May and again in November–December, using riverine transport. The aim of these joint surveys is to check the findings reported routinely from the lake area in Egypt and Sudan. A joint committee is to be formed to examine the achievements made and for exchange of technical experience.

Farid (1975) who described the Aswan High Dam and its lake, Fig. 13, discussed the ecological disturbances and health hazards arising from this project. With regard to malaria, he outlined the ecological and human factors that may favour the reintroduction of *An. gambiae* s.l. into Egypt from northern Sudan as shown in the following:

(a) During the seasonal fall in the water level of the lake which is estimated to be 5–7 m during January–July, many residual pools are formed. Despite intense evaporation, these pools retain sufficient water for mosquito breeding, and it would not be economically feasible to carry out antilarval operations in such extensive pools.

(b) The growth of vegetation along the shores or in the pools provides protection to the larvae of *An. gambiae* s.l. during the very short cold seasons but during the rest of the year, this vector prefers to breed in small sunny pools. The local vector, *Pharoensis*, prefers to breed in pools having aquatic vegetation such as *Potamogeton*. So far, very few vertical and floating vegetation has grown in the lake, but the presence of *P. pectinatus* in Khor El Ramla indicates that this aquatic weed will soon become established.

(c) The establishment and northward spread of *An. gambiae* s.l. in the lake requires clusters of human habitations, herds of domestic animals or even wild game along the lake shore. At present, these do not exist, or only in very small numbers. There are plans to set up 10 villages for fishermen and a number of agricultural settlements with a population of 200 000 or more. If this materializes, the chances for the establishment and northward spread of *An. gambiae* s.l. would be much greater.

(d) Passive transportation of *An. gambiae* s.l. may occur through boats or Nile steamers operating between Sudan and the High Dam harbours. At present, the lake shores are arid and hardly have any sizeable human settlements. This condition cannot favour the establishment of *An. gambiae* s.l. This situation will eventually change once the level of the lake stabilizes and new agricultural and industrial settlements become established. Vigilance on this vector at this stage should be concentrated around human habitation, in boats and in harbours. The routes of camel caravans from Eritrea and Somalia to Egypt which now operate along the Red Sea and may in turn operate along the lake, should be studied. Experience elsewhere has shown that *An. gambiae* s.l. can hide and survive in the belongings of the nomadic tribes (folded tents, boxes, potteries etc.).

Recent information comes from a report by Shidrawi (1980) who accompanied a joint survey team during April–May of the same year. In this report, the ongoing control activities undertaken in the Egyptian part of the lake were described. In northern Sudan, weekly larviciding continued as planned and DDT house spraying was applied twice annually covering a population of 48 000 living within 1/2 km on each side of the lake or south of the Nile. At Halfa, fogging of all trains and boats has been maintained. Since 1979, it has been mutually agreed to extend the control area to Lebab, 85 km south of Abu Fatma covering an additional population of about 160 000, making a total length of 800 km south of the High Dam. While the annual inspection by the joint survey team found nothing in 1979, research workers from Khartoum University collected considerable numbers of *An. arabiensis* (the only species of the *An. gambiae* complex identified so far from northern Sudan) at Dal island (see Fig. 14) during November–December of the same year.
During the survey of the joint team of 1980 in which Shidrawi participated, the breeding places were found to have been heavily treated with temephos as none was positive and no adults could be found in houses in six villages including Dal and Farka as well as Kweka (212 km south of Halfa). It was only in Attab village that both larvae and adults of An. arabiensis were found and at Sal Island (almost opposite Kweka) where only larvae of this species were collected. In this area (about 200 km south of Halfa), breeding occurred in vegetation away from the shores in the middle of the river and obviously were missed by the larviciders. The positive findings provided further evidence that the species could persist in its normal habitat and range of distribution. In his conclusions, Shidrawi re-emphasized that from the above observations, An. arabiensis has not been eradicated from the project area by the control measures undertaken so far and it is doubtful that this can be achieved. He reiterated the previous views that control measures in northern Sudan should aim at keeping the density of An. arabiensis sufficiently low to minimize its ability to spread northwards into Upper Egypt. In this connection, he pointed to the role that can be played by riverine and air transport and also underlined the potential danger when the lake shores become repopulated, thus facilitating the northward spread of the species.

Farid (1984) who accompanied the joint inspection mission, as a WHO Consultant during February-March 1984, reviewed the control measures undertaken by Egypt in the Lake Nasser area from Aswan to Abu Simbel, and by Sudan in Lake Nubia area (extension of Lake Nasser) from new Halfa to the south including the riverine area up to Abu Fatma in the northern province. In his comment on the findings of the mission, Farid (loc.cit.) pointed out that the absence of larvae and adults in the lake areas (although the most southern part was not covered due to difficult accessibility) as revealed by the mission and the records of routine surveys, as well as the negative blood slides obtained from schoolchildren in Abu Simbel and Halfa towns, together with the fact that every positive splenic enlargement was found in immigrants from Lower Egypt or Kordofan, Sudan, all give an indication of the absence of arabiensis from the lake areas with the exception of its unsurveyed southern tip. In the riverine area south of the Lake, larvae of arabiensis of different instars were found only at Tombos island adjacent to Abu Fatma (about 350 km south of Halfa) and further south at Kurelk village. However, these results should not be regarded as conclusive for various reasons, e.g., the improper timing of the joint inspection survey, the inability to survey the western riverine shores, the absence of records of routine surveys, the attempts of the local Sudanese gambiæ control team to larvicide heavily all breeding places before the arrival of the joint inspection mission, the low sampling rate applied by the mission in relation to the numerous suitable breeding sites, and the very large number of the indoor day-time resting sites in this heavily populated area. In his recommendations, Farid suggested that the timing of the annual joint inspection should be within October-November and to last for not more than three weeks. It should be preceded by a one-week meeting in Cairo or Khartoum to examine thoroughly the monthly reports submitted by the field staff of the gambiæ control project since the previous inspection, as well as any other technical reports (including meteorological, hydrological data recorded in the project area). Such monthly reports should include the results of entomological and parasitological surveys as well as control activities conducted against anophelines in the Egyptian and Sudanese parts of the project area. Examination of such reports and data should enable the joint inspection mission to select certain vulnerable localities in both Egyptian and Sudanese sides for inspection and to draw an itinerary to visit these places accordingly.

The most recent information comes from the report of the annual joint inspection mission (1987) covering the period 14 September 1987-18 October 1987. The report described the ecological changes and human settlements in the Egyptian and Sudanese parts of the gambiæ control project area. In addition to groups of fishermen previously established on the lake shores in the Egyptian side, small groups of population occupy certain localities and are engaged in limited farming. The notable development is the re-establishment of two villages: Kostol and Adendan on a creek extending from the eastern shores of the lake. In the two villages a small population started farming, but some of them left because of the lowering of the water level in the lake in 1986. They are expected to return when the project of floating water pumps is established. This area is considered a potential danger because of its proximity to the Sudan border (35 km north of Halfa), and the expected connection with the desert route planned to be constructed along the eastern side of the lake to connect Halfa and Aswan. On the Sudan side, many arable plots reappeared after the water level receded in Lake Nubia, and this attracted more
groups of people to repopulate the lake and the riverine areas for farming or raising domestic stocks. Entomological searches made in several localities in the Egyptian side of the lake did not reveal the presence of *arabiensis*, and likewise parasitological investigations yielded negative results. On the Sudanese side, the following observations were made in the three main parts of the project area:

(a) The northern part: from Halfa to Akama, north of Akasha
- the size of cultivated land appreciably increased;
- the size of the human population markedly increased;
- many potential breeding places and creeks were formed;
- in view of difficult navigation, the inspection mission could not reach by boat beyond the outskirts of Akasha;
- all adult and larval searches were negative for *arabiensis* in places inspected;
- parasitological investigations revealed five positive cases (3 *P. vivax* and 2 *P. falciparum*) all were classified as imported from New Halfa resettlement area, Khashm El Griba, Kassala province.

(b) The central part: from Akasha to Waw.
- *arabiensis* larvae were recorded in a very low density at Dal (about 150 km south of Halfa) [previously regarded the northern limit of *gambiae* s.l. - see above];
- further south, *arabiensis* was recorded as larvae at Mafrika, Atab and Waw, and as adults and larvae at Kweka, Aboud and Sai island - the density was very low at all these places;
- parasitological investigations gave negative results;
- all positive breeding places were immediately treated.

(c) The southern part: Abu Fatma.
- adults and larvae of *arabiensis* were recorded in small densities in four villages;
- parasitological investigations revealed two *P. falciparum* cases: one classified as a relapse and the other as indigenous.

The total number of blood slides collected by the mission in the Sudanese part was 3088 of which seven were positive as shown above.

Several recommendations were made of which reference is made to the following:

- to continue provision of motorized boats in view of the large number of potential breeding places in several islands and the western shores of the lake and the river Nile in the Sudanese part of the project;
- to survey and larvicide the wells and other non-classical types of breeding places of *arabiensis* as was revealed by the inspection mission;
- to expand the parasitological surveys to cover at least 10% of the human population; the surveys should be conducted once in November and once in March/April;
- to apply residual house spraying in places not covered so far;
- to determine the susceptibility of *arabiensis* to safe insecticides used as larvicides and imagoicides;
- to fill in vacant posts in view of the acute shortage of the available staff.

Bahar (1975) in an unpublished paper to WHO reviewing the malaria situation in water-resource projects in the WHO Eastern Mediterranean Region, referred to a favourable development in Egypt as a result of increased perennial irrigation water through the High Dam. In order to reclaim more land for production of food crops, the Egyptian Government decided to replace the open drains with covered drains. This measure was initiated for leaching the land, so as to free it from salts, and at the same time reducing the cost of maintenance of the drains. Hundreds of kilometres of open drains suitable for breeding malaria vectors and snail intermediate hosts of schistosomiasis, were thus eliminated.
In Jordan, Tawfik (1987) when describing the problems facing the Jordanian programme [see (ii), 1 above] explained that the area around Rutenberg dam on the Yarmouk river close to the junction with the Jordan river has also caused concern. An earth dam was built in 1970 to replace the gates on the Jordanian side which had been blown up previously. The earth dam, however, has no gates and no overflow system. As a result of this, the water in the dam reaches a higher level than it did before and consequently fields around the village of Bagura on the Jordanian side become flooded. Moreover, as no clearing is done in the lake, reeds and trees have covered an area estimated to be 2/3 of the surface of the artificial lake. This together with the flooding near Bagura provide an important source of mosquito breeding. Although no sacharovi or any other vector has been found breeding in this area in recent years, there is a danger of reintroducing sacharovi from areas further up the Yarmouk river where it is resistant to DDT and dieldrin in Syria. Two measures would eliminate the problem of mosquito nuisance as well as the potential danger of reintroduction of sacharovi:

(a) to maintain the water in the lake at a lower level by opening gates on the western side and,
(b) to clear the reeds and other emergent vegetation in the lake by a common agreement, of the parties concerned.

These measures should be done in addition to the larviciding which is at least being carried out on the Jordanian side.

In Israel, Kitron (1987) extensively reviewed the history of malaria in relation to agricultural development and described its control in Palestine/Israel, Italy and USA with special reference to the Tennessee Valley Authority. Only information related to Palestine/Israel is summarized here. Following the division of Palestine in 1948, Israel underwent a period of extensive agricultural and general development. In 1949, the Anti-Malaria Division was established in the Ministry of Health. In addition to its responsibility for all direct malaria control activities, this division was represented in the various agencies that supervised agricultural settlements, water-resources projects, drainage work, use of insecticides etc. The Subcommittee of the Organization of Maintenance of Drainage Projects was headed by the Director of the Anti-malaria Division. Moreover, his membership in the Insecticides Advisory Committee demonstrated the interaction between health and agricultural professions in determining the policy relevant to both. Another important aspect of the antimalaria activities in Israel was the strong coordination between the medical infrastructure and the public health organization. It was witnessed that there was no settlement left without some type of health facility. The population made liberal use of these freely available health facilities to the extent that malaria cases were unlikely to remain undetected, even in the absence of an active case detection programme. The classical measure of larval control through source reduction and the use of larvicides remained the mainstay of the malaria control programme in Israel. House spraying with DDT was applied sparingly and never became the principal method of choice. Surveys of different types were conducted, including a country-wide survey of all natural water sources and potential breeding places of anophelines. Under these measures, the number of malaria cases declined rapidly, despite the presence of parasite carriers among an influx of immigrants who also included susceptible persons. By 1966, indigenous cases were no longer seen. At present, Israel is free of indigenous malaria despite the continuing presence of four potential vectors: serpentii, superpictus, sacharovi and claviger, and the continuing influx of parasite carriers (e.g., from Ethiopia in 1984). Surveillance, antilarval activities, and monitoring of all breeding sites continue throughout the country. Almost every possible site is cultivated, all water sources are carefully managed, and nearly all settlements have running water and sanitary facilities. The literacy rate is high and infant mortality is low (13.9/1000 in 1980). Finally, Kitron considered that the probability of serious resurgence of malaria appears to be slim, as long as no major disruptions (e.g., wars) occur in the region.

Kitron & Spielman (1989) reviewed the measures adopted for suppression of malaria transmission through source reduction of anopheline breeding in Israel, the United States and Italy, of which reference is made here only to Israel. The authors described the control measures applied in Palestine since the early years of the century. Following the division of Palestine in 1948, source reduction remained the backbone of malaria control in the new state of Israel. Malarlol replaced solar oil and Paris green, and several herbicides and algicides were evaluated as agents for altering the conditions favourable
for the vector in the breeding sites. Standardized procedures for reporting of field activities were developed, and reports by regional inspectors to the central division were submitted biweekly during the breeding season of mosquitoes. DDT house spraying was extensively applied during the 1948 war, when the use of other antimalaria measures proved impracticable. Later, it was applied sparingly after the war, mainly in three regions in which malaria still existed: Jordan valley, Beit-Shean valley and Negev and Arava or southern desert, particularly in sites where immigrants from malaria endemic countries settled. The application of house spraying was gradually reduced. By 1966, no indigenous cases of malaria were recorded in Israel, but following the 6-day war of 1967, isolated cases were again reported from within pre-1967 borders of Israel. For applying antilarval measures, all breeding places whether natural or artificial, permanent or temporary were mapped and treated regularly. All direct antimalaria measures were carefully adapted to local conditions and to ecological characteristics of each vector. This required a thorough research on the bionomics of various anopheline vectors as well as on the course of the disease. Thus, the measures undertaken against sacharovi included the preservation of dense vertical vegetation in order to keep the water shaded and the use of Tilapia fish to reduce horizontal vegetation. Measures directed against sergentii included the use of Gambusia affinis, cleaning and clearing water beds to accelerate the current. Measures applied to control superpictus included drying stream beds weekly by diverting the water flow in different directions. Restricted water collections that could be drained were thereby permanently eliminated, while oil larviciding was applied in those breeding places that could not be drained. Large-scale drainage operations were sought for reducing the abundance of sacharovi and sergentii in particular. DDT house spraying was carried out mainly in the final campaign against sacharovi.

[See more details on malaria control measures in Israel by Salternik (1977a & b) under (ii), 1 above].

In Lebanon, Metwally (1970) in an unpublished report to WHO described in detail the area of Koura - Zghorta plateau and the Akkar plain where a hydro-agricultural development project which was planned to be initiated in 1969 and completed in four years. In 1970, investigations were started to select the sites for construction of dams and determine the volume of water to be received. Several infections existed in the area such as Ascaris, hook-worm, skin Tinea (ringworm) and ophthalmic diseases. Malaria which has been eradicated from the area [the malaria eradication programme in Lebanon entered the maintenance phase since 1969] may reappear as a result of the presence of swamps and stagnant pools arising from canal construction and related work. Water blockage may take place if there is an open canal irrigation system. Therefore, construction of drains is deemed necessary. The drains will also be suitable for snail breeding due to growth of aquatic weeds on their side. Vector control is mainly directed against culicine mosquitoes by the Ministry of Public Health, but it would be advisable to have such activities performed by the rural health centre planned to be established in the area. No further information could be traced on this project or any other water-resources projects in Lebanon.

In Syria, although there are 12 dams constructed between 1950 and 1971 (World Register of Dams, 1978), no information could be traced on malaria in areas under the influence of these dams. However, casual observations were reported by WHO Consultants/Entomologists. Eshghy (1986) mentioned that in many localities several water sources such as springs and shallow underground water create marshes and swamps of various sizes. Also, poor maintenance of canals and drains and the consequent growth of reeds and vegetation as well as the erosion of the banks, have slowed down the flow besides reducing the capacity of the system, thus providing favourable breeding places for anopheline vectors.

Further, Sadek (1986) mentioned that according to his discussion with the Director General of Agriculture and Irrigation in Chab valley, Sekallia/Hama, Syria, the clearance of marginal vegetation from all drainage ditches is done once yearly, but the growth of reeds is very rapid, being within a period of three months. This explains the presence of reeds practically all year round. The most obvious type of source reduction is the elimination of standing water in which mosquito larvae and snails breed. This can be done by filling in depressions and deepening permanent water bodies. Reviewing the 6th Five-Year Plan (1986-1990) of the Ministry of Irrigation, Damascus, with the Director of Irrigation, there are two projects under execution. The first is the deepening of El-Assi river (Hama and Homs) between Qatina lake and Mehredah dam, i.e., to form a narrow bottom
or a V shaped cross-section, so that the flow can continue without becoming a meandering channel. The second is filling in ponds and pools in Rakka and Der El-Zor which is the most satisfactory method for the permanent elimination of vector and snail breeding.

4. Alternative methods of vector control

Most of the available information that could be gathered from countries of the Mediterranean Basin under malaria control or in advanced maintenance phase, concerns supplementary measures or alternative methods to replace the standard methods of attack on vector populations. The information compiled here is conveniently grouped as follows:

4.1 Biological control

All the available information from the area under review concerns the use of larvivorous fish. The WHO report of the Travelling Seminar on the use of Larvivorous Fish for Mosquito Control in Anti-Malaria Campaigns, Bulgaria and USSR, 27 August-15 September 1979 - simply referred to here as WHO (1979) - compiled useful information on the availability and efficacy of larvivorous fish in many countries of the world including some of those occurring in the present geographical area. In the past, the use of larvivorous fish, notably Gambusia affinis, as a tool for malaria control had been actively pursued by many countries. With the advent of DDT and newer insecticides, interest in the utilization of this fish was decreased and almost forgotten. However, interest in larvivorous fish has been revived after the problems of insecticide resistance in several major vectors has created operational implications in a number of antimalaria programmes during the late 1960's.

In the USSR, Shumakov (1980) presented the scope of predatory fish in the control of malaria vectors in areas of intensive agricultural development. The construction of different types of water reservoirs and the development of hundreds of thousands of hectares of irrigated areas, including rice paddies in river flood plains and in non-irrigated tracts has resulted in increasing the number of places of mass breeding of mosquitoes and consequently the production of large vector densities in addition to the territorial redistribution of vector species. Thus, the potential danger of outbreaks of malaria and other infectious diseases of man and animals has become much greater. At the same time, mosquito control during the maintenance of malaria eradication was rendered difficult by the fact that highly effective chemical control methods were practically excluded on account of the hazards of environmental contamination and development of vector resistance to insecticides. This situation necessitated the development of an integrated system of mosquito control of which biological control would represent a main component. The most promising among biological control agents is the predatory fish. Gambusia has been successfully used for the control of mosquito larvae in water reservoirs and rice paddies, but its efficacy is confined to warm waters. The white amur, Ctenopharyngodon idella, is the most promising fish for the control of overgrown vegetation in reservoirs. The advanced fry of the white amur can be stocked not only in reservoirs but also in rice fields. The results of many years of study have shown that the condition of rice plots are very favourable for the development of advanced fry of this fish which destroys the preimaginal phases of mosquitoes. The white amur unlike Gambusia is a cold-water fish. At present, its northern thermal boundary is along the line of Leningrad-Moscow-Novosibirsk and the Far East of the Soviet Union. Experience has shown that the white amur can be used as a biological control agent in a much wider area in the USSR than the warm-water Gambusia. The possibility of raising advanced fry of the white amur in rice check plots and the high effectiveness of this fish in destroying preimaginal phases of mosquitoes enabled the development of a technique for biological control of mosquitoes. The details of this technique were described which can be read in the original paper.

In Greece, useful information was provided by Hadjinicolau & Betzios (1973) on the history of Gambusia affinis and on an experiment and observations in different areas of the country conducted in 1970 to evaluate its efficacy in controlling gucharovi. The decade 1930-1939 witnessed an intensive campaign for establishing this fish which had been imported into the country a few years previously. A number of ponds and other suitable water bodies in every district of Greece were selected and stocked with the fish to serve as natural Gambusia breeding places. These natural hatcheries were soon teeming with Gambusia. From these natural habitats large numbers of fish were collected
and released in various types of mosquito breeding places throughout the country. At the end of the decade, the fish was widely distributed and firmly established throughout the country. The objectives of this campaign were not so much to test and prove experimentally the efficacy of the fish against mosquitoes, as to distribute a well known effective predator in all mosquito breeding places wherever possible. With this objective in mind, very few data were collected on the effect of Gambusia on anopheline density and malaria incidence. The only available information came from numerous enthusiastic reports which generally agreed that:

- the fish were readily adapting themselves to a variety of conditions;
- they were multiplying fast in all types of water collections;
- they were doing equally well in fresh, brackish and mineral waters;
- while the fish were able to establish themselves in the permanent breeding places of sacharovi and maculipennis, they were unable to do so in the typical breeding places of superpictus because the fishes were washed away after heavy rains and flooding (citing Livadas & Sphangos, 1941).

There was no quantitative determination of the effect of Gambusia on the density of mosquitoes, only a vague statement was generally made implying that wherever the fish was firmly established, the mosquito density was greatly reduced. In 1936, a general stocking of all permanent breeding places of sacharovi, which was by far the predominant species in the lower part of the Lania plain, was undertaken by the Malaria Section of the Ministry of Health and the International Health Division of the Rockefeller Foundation. The entomological assessment of the effect of Gambusia on the anopheline population in the area was based on comparison of the larval and adult densities observed prior or during the distribution of the fish with the densities recorded during subsequent years up to 1940. In 1936, during the process of distributing the fish, sacharovi larvae were so dense in Thermopylae breeding places that one dip in any spot of the breeding place could collect large numbers. In the following year, the larval density in the same breeding places was considerably lower, and during 1938-1940 the drastic reduction in density was striking. If one dipped in the same breeding place, one would most probably catch fish rather than larvae. Regarding the adults of sacharovi, regular collection from a stable near Thermopylae produced very large numbers ranging from 1000 to 2000 per day during the peak season, July-August 1936. In the following years, the density fell abruptly and the total catch from the same stable in the peak season yielded at the most a few tens of sacharovi. No larviciding or any antimalaria measures were undertaken in Thermopylae area during 1936-1940. The steady drop in the adult density of sacharovi must have been, therefore, due to the effect of Gambusia and not to weather or any other factor. With regard to the effect on malaria transmission, official documents of the Ministry of Health during that period showed a significant progressive decline of the spleen rate in schoolchildren of three villages in the lower part of the Lania plain, from 81.4% in 1935 to 32.9% in 1941. The parasite rate also progressively dropped from 34.3% in 1935 to 6% in 1941. During the years of World War II, the work on Gambusia came to a standstill. With the advent of DDT after the war ended, and its widespread use which made a spectacular impact on vector populations and consequently on malaria, the role of Gambusia was completely forgotten or even ignored. By the end of the 1960's, Gambusia was widespread and could be seen in large numbers in several permanent water collections in every district in Greece, including the permanent breeding places of sacharovi and maculipennis. It became obvious that in every district, breeding places of the two vectors which had no Gambusia, harboured large numbers of anopheline larvae. This was also confirmed in 1970 when the authors visited several localities in Greece, noting the absence of sacharovi wherever Gambusia was present. In Marathon lake which is the main water reservoir for Athens, not a single Gambusia could be found. According to information provided by the Director of Waterworks, Gambusia was present in large numbers since the construction of the dam up to 1954. In that year, Marathon lake was connected with an inlet from Iliki lake, another freshwater lake. With the waters from Iliki, a species identified as Barbus vulgaris (Pam. Cyprinidae) found its way into Marathon lake. A gradual but steady reduction in the density of Gambusia was observed until it completely disappeared. This provided evidence that B. vulgaris has been an effective predator of Gambusia.

Hadjinicolaou & Betzios (loc.cit.) conducted a preliminary experiment aimed at testing whether Gambusia could be transported economically in good condition from relatively long distances to a patch of rice fields. No special effort was made, at this stage, to
quantify the degree of effectiveness of Gambusia on mosquito populations in this particular patch of rice field. For transporting Gambusia, empty petrol cans were cut in half and fitted with a wide perforated lid for aeration, covering practically all the upper opening. These cans proved very practical, easy to handle and not expensive. In each can a maximum of 100 fully grown fishes could safely be transported from the breeding pond to the rice field. Fish nets (similar to ordinary entomological collecting nets) fitted with long handles were used for sweeping fish from the edge of the pond. Altogether 30 cans were transported in a Landrover to the rice field in one trip. No mortality was observed among fish as the roads were quite good and the distance covered was not more than 25 km. Gambusia releases commenced on 8 July 1970 and continued for 14 consecutive working days. Over a total area of about 860 stremas (about 85 hectares), Gambusia was distributed at a rate of 25 individuals per stremma (or about 250 per hectare). In another patch of 120 stremmas (12 hectares) the fish were released at a rate of 100 per stremma (1000 per hectare). Altogether, 33 700 were released in this rice field. Estimation of larval density [species not mentioned, probably sacherovi] was made on 8 and 9 July when the first releases were made, and periodically thereafter with 100 dips at each inspection. The larval index was based on the number of the 3rd and 4th instars; younger larvae and pupae were excluded. The larval index at the time of releases was 4.25 larvae/dip and subsequent inspections yielded the following:

<table>
<thead>
<tr>
<th>Date</th>
<th>Area treated at 25/streema</th>
<th>Area treated at 100/streema</th>
</tr>
</thead>
<tbody>
<tr>
<td>27 -28 Aug</td>
<td>0.29/dip</td>
<td>0.15/dip</td>
</tr>
<tr>
<td>1 - 2 Sept</td>
<td>0.18/dip</td>
<td>0.03/dip</td>
</tr>
<tr>
<td>16 Sept.</td>
<td>-</td>
<td>Nil(only 7 dips made)</td>
</tr>
</tbody>
</table>

The authors admitted that due to the absence of control patches these data cannot be interpreted quantitatively. The data, however, merely show that when Gambusia is present in adequate numbers in rice fields for a sufficient period of time, the larval density can be considerably reduced. This is empirically quite known, but it has not been sufficiently proved. Therefore, it is necessary to carry out systematic observations for a long period of time in a suitable rice field with comparable patches as controls.

Vassiliou, Fytzas & Ioannou (1985) investigated the toxic effects of insecticide aerial spraying on Gambusia in Greece. Every summer about 500 000 ha (50 million olive trees) are treated with organophosphorous insecticides against the olive fly, Dacus oleae. The investigation of toxic effects was made after aerial application of fenithion by determining the brain cholinesterase inhibition as well as the insecticide residues in the body of the fish. Large numbers of Gambusia were found in estuarine areas, irrigation channels and marshes near the application site. About 1000 adults of Gambusia (2.5 cm long) were obtained from a stock maintained at the Benaki Institute. They were transported to the area where the application was to take place and were acclimatized. On the day of application, the fish were placed in plastic containers filled with water from the stock colony, at a rate of 50 individuals per container. The containers were placed randomly at preselected sites among rows of olive trees. A gentle stream of air was constantly pumped into the containers by portable pumps. The field was properly signalized prior to application so that a uniform treatment could be performed. The application rate was 90 g fenithion/ha. Two hours after the application the containers were transferred to the laboratory where they were kept in the open air until the time of determinations was due up to 48 hours after application. After 48 hours, only small amounts (0.29 ppm) of the insecticide were found, and 93% of the brain cholinesterase activity was restored. Low concentrations of fenithion in the water (0.123 ppm) correspond to a proportional regeneration of the enzyme in the brain (73% from 42% initial enzyme activity). These results led the authors to conclude that aerial application of fenithion causes some short-term environmental damage. Longer periods of testing should show the ecological significance of this application.

In Turkey, Giglioli (1979) indicated that great hopes were placed on larvivorous minnows of Cynolebias, Aphanius, Rasbora and particularly Gambusia. While reports of control of sacherovi by G. affinis in Greece were encouraging, results in Seyhan, Turkey were disappointing. High mortalities in Gambusia were observed in ponds where migrant workers washed insecticide containers. In an unpublished report to WHO, Unori & Muir (1978) stated that during their visit to Adana plain many places were seen where Gambusia
coexisted with high densities of sacharovi in canals choked with aquatic vegetation (Chara sp.). It is, therefore, obvious that the usefulness of Gambusia under the prevailing conditions in the Adana plain is limited to areas of relatively open water. As shown under (ii), 1, above, the report of the Joint Meeting of the Ministry of Health and Social Assistance, Turkey and WHO, 1985, suggested that further attempts may be made with the cooperation of the General Directorate of Fishery Products to use herbivorous fish concurrently with Gambusia.

In most countries of North Africa, Gambusia exists since its importation in 1929-1930, but quantitative evaluation of its efficacy on local vectors is scanty or lacking. According to the report of WHO (1979) G. affinis holbrooki has been established in regional hatcheries in certain countries. The fish action can be hindered by the presence of aquatic vegetation, but in rice fields the density of anopheline larvae could be reduced by 90-95%.

In Morocco, the WHO report (1979) shows that Gambusia was imported into the country 20 years previously. Its population has been stable. It has not been closely evaluated, but it was observed that in 30 large ponds where the fish was introduced, the Anopheles and Culex larvae practically disappeared.

In Algeria, G. affinis holbrooki exists since its importation in 1930. It is widespread and several authors recommended its full utilization for larval control in permanent and semi-permanent breeding places. As mentioned under (i), Lefèvre-Witrier (1968) indicated that starting from 1946, G. affinis holbrooki has been utilized for control of breeding places at Théâr, Tassili N’Ajjer. Ramsdale (1972) who made larval surveys at two villages in Ouargla oasis in northeast Algeria, found that many surface water collections contained Gambusia and were free of mosquito larvae. Only one larva of multicolor could be found among a dense tangle of roots in water containing Gambusia. In contrast, all surface water collections into which Gambusia was not introduced were heavily infested with multicolor, the only anopheline species detected in Ouargla. The fish have been present in this oasis for many years, but there was no rational system for introducing them into a newly created situation. On the other hand, an expensive oil larviciding programme was in operation, which achieved little, as many breeding sites were seen where the oil was dumped at one end, or around the edges, whilst the remainder of the water surface was teeming with larvae and pupae. Therefore, it was suggested that antilarval measures should be based on the dissemination of Gambusia. If this is properly carried out, better control of multicolor larvae could be achieved at a fraction of the cost of the current oil larviciding and spraying operations. In Ouargla, well-defined and easily traced water collections exist and Gambusia is already widely distributed and dense in places where it exists. It requires a man with a bucket and a catching net to transfer the fish from populated to unpopulated sites. The distance involved is usually only a few metres. Nevertheless, because new water collections are constantly being created, the dissemination of Gambusia should be a continuous operation which must be followed. Division of the oasis into small sectors was suggested, each of which must be visited by a distributor of fish on the same day each month. This would facilitate supervision and evaluation of this biological control measure. At the same time many prolific breeding sites, especially in built-up areas, could be eliminated at little cost by filling. This would be the most effective and permanent of all anti-mosquito operations. In a further assignment, Ramsdale (1973) visited Biskra (Aurès Wilaya) where the problem of persistence of malaria transmission was almost resolved. The ecological conditions in Biskra region were significantly modified from those which prevailed in the previous year. The water in streams which remained abnormally high since the flood disaster of 1970 subsided considerably and the majority of pits among palm trees and the trenches in the area of Megloub-Bouchagroune which had constituted rich anopheline breeding sites dried up. In the area of Megloub-Bouchagroune and Togla, however, some pits and trenches still contained water, but they were treated regularly with temephos. The long trench system of Ain Oumache has been well controlled by the application of temephos or by the introduction of Gambusia. The rivers which flow from Ain Oumache are now without vegetation, and this assured an uninterrupted flow in them, and at the same time permitted Gambusia to reach, without obstacles the most infested corners. Searches at sites which were previously infested with sergentii and multicolor produced only some 1st and 2nd instar larvae of culicines. The report of WHO (1979) showed that G. affinis holbrooki is found in natural habitats and small hatcheries all over Algeria. It was found effective against larvae of labranchiae and multicolor, but details were lacking. In Quelma, considerable reduction
In labranchiae larval density was recorded, and in Ouragla breeding places were completely negative for larvae wherever Gambusia was abundantly present. The latest information comes from a report by Oddo (1984) who visited Algeria to assist in the evaluation of the malaria epidemiological situation and in drawing directives for the antimalaria action in 1984. He pointed out that it was impossible, as in the previous missions, to evaluate the antilarval operations due to lack of periodic reporting. Nevertheless, there were clear indications that the programme of distribution of Gambusia in the most receptive areas (the eastern region and certain Saharan oases) has materialized regularly.

In Tunisia, Wernsdorfer (1973) indicated that Gambusia fish were utilized on a large scale for the control of anopheline breeding during the period of the malaria eradication programme in all regions where the application of larvicides was impracticable. The fish were well distributed and contributed to the reduction of anopheline populations, particularly in the southern region. Nevertheless, very large numbers of Gambusia colonies were destroyed during 1971–1972 when molluscicides were applied to control schistosomiasis snails. It was not known when Gambusia colonies could be re-established. During a visit to Tunisia, Oddo (1979) reviewed the activities carried out by the entomological team. These included the dissemination of Gambusia and herbivorous fish. Two new reservoirs for rearing Gambusia were established in the regions of Mendjez-el-Bab and Béjā, and 27 permanent larval breeding sites were seeded with Gambusia. Later, Smolinski (1981) found that 19 new natural reservoirs of Gambusia were discovered in 1980 in the regions of Jendouba and Gafsa from which the dissemination of fish into permanent anopheline breeding places progressively proceeded.

In Libya, no information is available on the presence and use of larvivorous fish according to the report of WHO (1979).

In Egypt, Halawani & Shawarby (1957) mentioned that the distribution of Gambusia sp. was among the methods recommended by the Antimalaria Commission in 1928 for anopheline control. When the Malaria Research Station was established at Khanka in Qalubya province in 1930, it started to apply the recommendations of the Commission including the filling in or draining seepage ponds, construction of drains, distribution of Gambusia in mosquito infested channels, clearing vegetation from drains, applying Paris Green and/or Malarion as larvicides, and later residual house spraying when DDT became available in 1946. No further information could be traced on the use of Gambusia against anopheline immature stages in Egypt. Only a few experiments were conducted for the control of culicine larvae in wells through the use of Gambusia with success.

In Cyprus, according to information in the report of WHO (1979) Gambusia existed since it was imported into the country 30 years previously. The main stocks are kept in tanks and pools and have been disseminated in wells, ponds, natural and man-made lakes, marshes, streams and ditches. The fish has been an important tool in dams and ravines where larviciding cannot be applied. Through the use of Gambusia, breeding of anophelines and culicines in places which could not be dealt with by larviciding has been eliminated.

In Jordan, according to the report of WHO (1979), Gambusia was introduced in the late 1950's in the Jordan Valley for larval control in marshes around the Dead Sea. Breeding ponds of Gambusia were established at the Entomological Field Station in Jerico, and these became the source of supply for Syria. No evaluation has been conducted on the efficacy of the fish. Due to administrative difficulties the active use of the fish has been abandoned.

In Israel, Saliternik (1955) in his review of the biology of sergentii expressed his views with regard to the use of biological control for sergentii. The fish, G. affinis and Tilapia which have frequently been used locally for the control of the immature stages of anophelines, showed very limited success against sergentii, since this species often breeds in very shallow seepages or overflow where the fish cannot survive. Also, it has not been practical to increase the salinity of sergentii breeding places, because water currents in its usual breeding sites would rapidly dilute and wash away the increased salt concentration. Specific measures against the immature stages of sergentii were not included in the regular schedule of work of the antimalaria inspectors, because the breeding sites were often transient and unpredictable. Instead, some time was devoted to looking for suspected breeding areas in order to discover any new source of breeding which may have developed. These new breeding areas, very often artificial in nature, e.g.,
overflowing irrigation channels, leaking fish ponds, were treated with larvicides and then
listed for future inspection and treatment if necessary. Salternik (1957) further gave
his views regarding biological control of sacharovi in Israel. Since the breeding of this
species would cease in water having salinity above 0.7%, it may be controlled in swamps
adjacent to the sea by flooding them with sea water to raise the salinity above that
level. G. affinis may be introduced and prove effective, but only after horizontal
vegetation has been cleared. In concrete reservoirs or pools whose surface is covered
with filamentous algae, Tilapia fish may be introduced as these will destroy and consume
the algae, thus rendering the conditions unsuitable for sacharovi breeding. For
controlling sergentii and superpictus breeding, Salternik (1974) pointed to the combined
measures used in Israel, viz: alternating stream flow direction, periodical drying up of
stream beds, introduction of G. affinis into streams, drainage and larviciding operations.

In Lebanon, Gambusia was introduced during 1944-1945 in Nahr Damaver and in Nahr
Beirut and in Nahr Ibrahim during 1962-1963, according to information shown in the report
of WHO (1979). The fish is now available in natural habitat and streams but no evaluation
has been made.

In Syria, according to the report of WHO (1979), Gambusia were brought from Jerico,
Jordan in 1962, by the late Dr L. Mara, then WHO Malarialogist. The fish were seeded in
a large water collection near Aleppo and proved very effective as anopheline larval density
decreased drastically. From this source, Gambusia were introduced to several areas in the
country, namely Ghab, Lattakia and Tartous provinces. The fish now exist in principal
hatcheries and in natural habitats. Difficulties have been encountered in handling the
fish and its maintenance in new habitats. From the report of Sadek (1986), a trial was
arranged in August 1982 to seed Gambusia in many permanent water bodies such as Sen lake
in Harison and other localities in Tartous province, but unfortunately the follow-up was
totally neglected. According to observations by Sadek, the fish thrived and was
associated with very low density of sacharovi in lakes, streams and drains as well as
irrigation reservoirs in Harison, Tartous province; Ghab, Hama province; El Rooge, Idleb
province; and El-Mazarib, Daraa province. Sadek, therefore, recommended that the use of
Gambusia should be pursued to replace larviciding wherever feasible. To be effective, the
fish density should be sufficiently high (5-6 fishes/m²). Cooperation with the General
Establishment of Fisheries was stressed as they have the equipment and experience for
large-scale transportation of the fish.

B. thurinigiensis H-14 was tried in Turkey and proved effective, but its cost could not
be afforded by the budget of the antimalaria programme - see under (ii), 1 above.

4.2 Space spraying

In Turkey, outdoor malathion fogging and indoor winter fogging with Neopybuthrin as
well as ULV application with pirimiphos-methyl were used in Chukurova plain but these
operations were not assessed entomologically nor epidemiologically - see under (ii), 1
above. It was suggested that these operations may be discontinued as from 1985.

In Egypt, in an attempt to find a suitable method for controlling pharoensis, the main
vector of malaria, a trial was carried out in 1966 to apply malathion and temephos by
aerial spraying as was reported on by Mahdi, Taha & Ezz El-Arab (1967). A hamlet of 50
houses with about 300 inhabitants, situated among rice fields of about 160 acres (0.8 x
0.8 km) was selected for the trial in Kafr El Sheikh governorate in the Nile Delta. A
similar area situated at about 20 km away was selected as control. Aerial spraying of a
mixture of malathion ULV and temephos at a ratio of 9:1 was applied through 6 flat-fan
nozzle tips (size No. 80015) at a rate of 0.25 l/acre. The flight was 6 m high giving a
swath width of 30 m. The applications were made at 10-day intervals from 17 August to 16
September. Operations were carried out early in the morning when winds were almost nil.
The pilot was guided through two ground flag men. The trial was assessed entomologically
by estimating the density of pharoensis resting indoors by PSC, those exiting in outlet
window traps installed in local houses, and those biting man. Parous rate determination
was made on samples drawn from man-bait capture. Pre-operational base-line data were
obtained one week before application, and post-operational observations were conducted one
and two months after application. The density of pharoensis by PSC and window trap as
well as the man biting rate fell sharply one month after application compared with the
base-line and data of the control village. However, all indices rose again two months
after application. The parous rate (38%) remained similar to that recorded in the control village (40%) one month after application and was even higher (73%) in the treated village than in the control village (58%) two months after the application. The authors postulated that the lack of reduction in the parous rate was due to the effect of the aerial spraying on the larval population and the outdoor fraction of the adult population. In contrast, the action of residual house spraying differs in that it reduces the probability of survival of the house-haunting population. A more plausible explanation was offered by attributing the lack of response in the parous rate to the brief period of the residual effect (1-2 days) of the aerial spraying being applied at intervals of 10 days. This would have been prolonged, if the application of agricultural pesticides coincided. In fact, aerial application of pesticides on cotton plantations in the surroundings early in the season affected pharoensis populations to the extent that the pre-operational parous rate (base-line) was much reduced in both the trial village (6%) and control village (18%). The authors, however, considered that from a malaria transmission point of view the lack of effect on the parous rate is compensated by the reduction in pharoensis density. They further assumed that the effect on numbers will be maintained under the pressure of aerial spraying in view of the great susceptibility of pharoensis to malathion and the remote possibility of selection for OP resistance under field conditions. [This assumption was made when pharoensis was still susceptible to malathion, but things changed later as it exhibited pronounced resistance to OP compounds including malathion, as well as carbamate insecticides – see under (i), 3.12 above].

Another trial of aerial spraying was conducted in Marg locality with extensive rice cultivation near Cairo during August 1971, using iodofenphos as reported on by Kamei et al. (1972) Two villages were selected for a single treatment with 20% iodofenphos ULV formulation (Nuvanol N 20 U): one village with 50 ha rice cultivation was sprayed at a dosage of 3 l/ha, and the other with 120 ha rice cultivation was sprayed at a dosage of 1.5 l/ha. A third village with comparable conditions remained untreated as control. The susceptibility of pharoensis and Cx. pipiens to iodofenphos was ascertained using the WHO test procedures for larvae and adult mosquitoes. Entomological evaluation was made utilizing the following techniques: PSC in houses, outlet window traps, man-bait capture, larval dipping, and exposure of caged adult mosquitoes, and larvae in paper cups. Determination of the parous rate was also made on samples drawn from man-bait capture. Briefly, applying ULV iodofenphos formulation from a Pilatus Porter aircraft at a height of less than five metres over open rice fields and swath width of 30 m showed that either 3 l/ha or 1.5 l/ha was very promising. All aquatic stages and adults of mosquitoes nearly disappeared for a period of about 10 days. No other trials of insecticide aerial spraying have been made in Egypt. [Cost-effectiveness of this type of application was not determined in any of these trials].

In Syria, Sadek (1986) mentioned that in 1985, a ULV aerial application of an insect growth regulator (Dimilin) was carried out in Ghab area during May and September at 11-21 day intervals. Entomological evaluation revealed that pre-application larval density of sacharovi was not sufficiently high to draw meaningful conclusions after treatment. Since 1981, winter fogging with 50% pirimiphos methyl EC and 40% Bromophos EC has been applied but no information was provided on the effect of this type of application on vector populations.

4.3 Integrated vector control

No information could be traced on integrated malaria vector control trials or operations based on a combination of cost-effective and safe methods carried out in any country undertaking malaria control in the Mediterranean Basin. Only a village scale trial was implemented in the southern part of the Nile Delta, Egypt, but dealt mainly with culicine mosquitoes and houseflies.

5. Community participation

In Turkey, Lassen (1982) underlined that community participation can only be developed through a well designed health education programme aimed at promoting the knowledge, and changing the attitudes and practices of the people. The persons involved in fostering community participation will have to count primarily on the support of key figures who constitute the leadership in rural communities. In Turkey, the potential key figures are:
(a) The Mukhtar: This is the person elected by the people of a village and paid by the government. He represents the village in all dealings with civil administration. He registers deaths, births and marriages, and is also responsible for notifying the administration of any case of communicable diseases detected in his community.

(b) The Imam: He is appointed and paid by the government as the religious leader of the community. He thus advises on religious and moral matters and is highly respected. His role as an educator makes him an important person in health education.

(c) The teacher: He is appointed and paid by the government with the responsibility of educating children. His profession makes him a very valid aid in health education.

(d) The midwife: She is appointed and paid by the government. The rural midwives live in one of the community groups. The responsibility of the midwife in health matters is wider than mother and child care nurse. Her position as a health maker, living in the community and being in close touch with every day problems makes her a valuable person for all health matters.

(e) The community opinion leader: In all communities, there are persons who adapt more quickly than others to new ideas and methods. These people may influence others and their support in fostering changes can be very valuable.

(f) The village elder committee: This is composed of 8-12 members elected by the people of the community. The Imam and school director are de facto members but there is not any representative for health. The committee meets weekly and discusses community problems including health. By virtue of the high esteem enjoyed by this committee, its contribution to the promotion of community participation is invaluable.

(g) The health committee: At present health committees do not exist at village level, although it is the intention of the government to establish them. At provincial level, and in the municipality of Adana, health committees exist under the chairmanship of the Governor and the Mayor. However, there still remains much to be done regarding the definition of terms of reference and authority of these committees.

In the report of the Joint Meeting of the Ministry of Health and Social Assistance, Turkey and WHO, 1985, it was stated that inadequacy of community participation and intersectoral cooperation is a major constraint which has vital impacts especially on source reduction activities – see under (ii), 1 above.

No information could be traced on community participation in relation to malaria vector control in other countries of the Mediterranean Basin undertaking antimalaria activities.
CONCLUSIONS (SECTION IIIA)

Valuable knowledge has been accrued from studies in several countries of the Mediterranean Basin (see Fig. 1) on vector bionomics, varying in their aims and intensity. Good knowledge has also been accumulated from epidemiological studies and control experiences on the role of vectors and their reaction to attack measures. Available information has been compiled on seven species: atroparvus, maculipennis s.s., labranchiae and sacharovi of the An. maculipennis complex, sergentii, superpictus and pharoensis as potential or active main vectors, as well as four species: hycanus, claviger, hispaniola, d'haill, multicolor as secondary or suspected vectors. In certain instances, when recent information is not available, resort was made to old knowledge to form a background, on the basis of which updating studies could be planned.

The most complete knowledge on aspects of vector bionomics comes from the USSR where several anopheline species act as potential vectors (Artemiev, 1980). In continental Europe, as part of vigilance on potential vectors, studies have recently been conducted in France (larval surveys), Italy (larval and imago surveys), Romania (larval and imago surveys) and Yugoslavia (imago surveys).

Of members of the An. maculipennis complex, labranchiae extends its existence to North Africa up to Tripolitania in Libya in the east, where it acts as an active or potential vector in the northern part of Morocco, Algeria, Tunisia and Libya. The other member of the An. maculipennis complex is sacharovi which occupies the eastern part of the Mediterranean Basin acting as an active vector in Turkey and Syria and a potential vector in Jordan and Israel joined by two other potential vectors sergentii and superpictus. No member of the An. maculipennis complex or An. claviger group exists in Egypt where pharoensis is the main vector. An. sergentii occupies the southern parts of North Africa as an active vector in the oases of Morocco, Algeria, Tunisia, Libya and joins pharoensis in the oases of the western desert of Egypt and in Fayyum governorate.

On breeding habitat and spatial and seasonal distribution, good information comes from Turkey on the most important vectors sacharovi and superpictus, but these aspects need to be restudied specifically in Chukurova/Amikovasa agricultural scheme where malaria transmission remains an important problem. Some observations have been recently initiated in Chukurova area on the seasonal distribution of sacharovi and its relation to malaria incidence (Mimioglu, Kasap & Kasap, 1988). These aspects also await updating in Morocco where malaria transmission persists in several foci with labranchiae being the main vector, and in Syria where transmission continues in a limited number of foci with sacharovi and superpictus in certain places acting as the main vectors. There is also a need to study in depth the breeding habitat of sergentii in the oases of the Algerian Sahara where a small number of indigenous cases has recently been recorded. Larval and adult vigilance surveys need to be maintained along the trans-Saharan highway crossing Algeria (see below). Receptivity studies are now important in Libya and Tunisia where malaria transmission has been interrupted, but there is an influx of imported cases through immigrants (see below).

Good examples have been provided pointing to environmental changes that resulted in drastic changes in the breeding habitat and spatial distribution of potential vectors in continental Europe, viz: disappearance of labranchiae from southeast Spain through discontinuation of rice cultivation, improved drainage and agricultural practices, application of agricultural pesticides besides residual house spraying (Blazquez & Zulueta, 1980); disappearance of labranchiae and sacharovi from certain areas in Italy through elimination of swampy areas, pollution of water with industrial wastes, herbicides and agricultural pesticides (Coluzzi, 1980); disappearance of sacharovi from the Danube and Dubrudja area in Romania through residual house spraying followed by almost complete elimination of many breeding sites due to extension of agriculture and improvement of water management, reduction in draft animals as a source of food as a result of mechanized agriculture, and the application of pesticides in agriculture and farm houses - these factors have also led to changes in species composition of former malaria vectors, namely atroparvus, mesease and maculipennis s.s. in the area studied in Romania (Biblìe et al., 1978); elimination of maculipennis s.s. from Lamia plain in Greece through drainage work and land reclamation, and likewise elimination of superpictus from the plain through diversion of a hilly stream to be used for irrigation (Hadjiinicolaou & Betzios, 1973a). On the other hand, examples are available on incidents of spread of potential vectors to areas where they did not exist before or were scantily present, viz: labranchiae in San Donato area, Grosseto province, Tuscany, Italy, following rice cultivation (Bettini et al., 1978); breeding places with high salinity populated by sacharovi in southeast Macedonia where this species never existed and may have migrated across the border from Greece (Lepez & Vitanovic, 1962).
Knowledge on the breeding habitats of pharoensis and sergentii in Egypt have recently been updated. Rice cultivation was found to be an important factor influencing the density of pharoensis, both by extension of the breeding areas and by enhancing the humidity conditions to a level favouring adult survival. Breeding habitats of sacharovi, sergentii, superpictus and claviger had been well studied in the past in Palestine/Israel. Although anopheline breeding is still being monitored longitudinally in Israel as part of vigilance on the reintroduction of malaria from imported cases, there is a need for more specific observations on the seasonal prevalence of potential vectors particularly sacharovi. This species after disappearing for almost 10 years as a result of control measures, reappeared in 1971, and seems to have changed its seasonal pattern. It was suggested that accurate determination of its seasonal distribution would show whether this change in part of its adaptation to its former habitats (Pener & Kitron, 1985a & b). In Jordan, the densities of sacharovi, sergentii and superpictus are also continuously monitored as part of vigilance because of the risk of resumption of malaria transmission from the large influx of imported cases (Tawfiq, 1987).

On vector dispersal, useful knowledge is available from past observations on labranchiae in Algeria (Collignon, 1959); sacharovi, sergentii and superpictus in Israel (Saliternik, 1957 & 1974); sacharovi in Syria (Solliman, 1961a); and more recently sergentii in Siwa oasis in Egypt through mark/release/recapture experiments (Abdel-Malek & Abdel-Aal, 1966). Migratory flights of sergentii and superpictus in Lebanon, and of pharoensis in Egypt and Israel were described (Garrett-Jones, 1950, 1957 & 1962). More up-to-date information on dispersal would be useful particularly with regard to sergentii in the oases of the Algerian Sahara and the western desert of Egypt where it may be possible to eradicate this species through genetic control techniques.

On vector biting and resting habits good information has been provided from Turkey on sacharovi and superpictus (Postiglione, Tabani & Ramsdale, 1973), but this needs to be validated by specific observations on Chukurova/Amikovasi area. Useful information was obtained from Sicily, Italy on the distribution of labranchiae in indoor and outdoor resting sites by means of a mark/release/recapture (Cefalo, Oddo & Saccà, 1961). Scanty information on biting and resting behaviour of labranchiae in Morocco as well as sacharovi and superpictus in Syria, but more intensive observations on the two aspects are needed in the two countries. Also, intensive biting and resting observations are needed on sergentii and multicolor in the oases of the Algerian Sahara. Detailed information is available on the biting and resting behaviour of pharoensis in Egypt (Zahar et al., 1966) which has been updated and included sergentii in Faiyum governorate (El Said, et al., 1986). Good knowledge on biting and resting behaviour of sergentii and its refractory response to residual house spraying due to its exophilic tendency that necessitated the addition of larviciding measures, comes from Jordan and Israel (Farid, 1956 and Saliternik, 1955 & 1967).

Light traps (CDC and modified types) have been successfully used for sampling of labranchiae and sergentii populations in Morocco (Bailly-Choumara, 1973a & b), and pharoensis populations in Egypt (Huribut & Weitz, 1956). Using dry ice with New Jersey light traps increased the yield of sergentii in a limited attempt in Israel (Saliternik, 1967). A single attempt made in Syria with CDC light traps failed. The experience from Morocco agrees well with the general conclusion obtained from some trials in East and West Africa in that the light traps cannot replace the epidemiologically relevant technique of man bait capture, but may be used as a supplementary tool for collecting mosquitoes for dissection and for determining the seasonal distribution of vectors, as well as sampling exophilic species that cannot be found resting in houses.

On host selection, the most recent information comes from the results of precipitin tests carried out during 1971-1974 concerning labranchiae and sacharovi. Even the latest information concerning sergentii and superpictus in the Mediterranean Basin comes from earlier results recorded during 1959-1964, with the exception of a single record of sergentii in Tunisia obtained in 1971 involving a small sample of bloodmeal smears analyzed. On the other hand, knowledge on the HBI of vectors in Egypt has recently been updated: pharoensis in Aswan governorate (Kenawy et al., 1987); pharoensis and sergentii in Faiyum governorate (Beier et al., 1986); sergentii and a small sample of multicolor in Siwa and Gara oases (Kenawy et al., 1986). The epidemiological relevance of HBI in areas under malaria control or as part of receptivity studies in areas under the maintenance phase is quite well known. Therefore, it should be updated taking into account the changes in
environmental conditions including man:animal ratio associated with socioeconomic
development. At present, the gaps in knowledge of HBI are:

- sacharovi and superpictus in Turkey;
- labranchiae in Algeria, Morocco and Tunisia;
- sergentii in Libya;
- sacharovi, sergentii and superpictus in Israel and Jordan;
- sacharovi and superpictus in Syria.

On vector longevity, interest in age-grading seems to have waned. Apart from the well
known studies in the USSR, attempts made to utilize the age-grading techniques in countries
of the Mediterranean Basin were as follows:

- Sicily, Italy, to determine the effect and after effect of DDT spraying on
  labranchiae populations (Cefalù, Oddo & Saccà, 1961 and Valentino & Bruno Smiraglia, 1965).

- Algeria and Morocco, to determine the vectorial efficiency of claviger, hispaniola
  and sergentii under unsprayed conditions (Guy & Holstein, 1968), but no attempts have been
  made to determine the impact of attack measures on longevity of labranchiae and sergentii
  populations.

- Libya, to determine the longevity of multicolor in the oases of Fezzart province
  where this species was regarded as a vector only on epidemiological grounds (Shalaby, 1971

- Egypt, to determine the impact of residual house spraying on pharoensis populations
  in insecticide trials (Zahar et al., 1966 and Shawarby et al., 1967a, b, c & 1968); or
  aerial spraying on pharoensis populations (Mahdi, Taha & Ezz El-Arab, 1967 and Kamel et
  al., 1972); and to determine the differences between two villages varying in malaria
  transmission effected by pharoensis and sergentii in Faiyum governorate (El Said et al.,
  1986).

- Syria, a limited trial to determine the impact of permethrin house spraying on
  sacharovi (Sadek, 1984).

The steady progress made towards interruption of malaria transmission together with
the shortage of qualified and experienced entomologists in several countries in the
Mediterranean Basin seem to have minimized the need for determining the longevity of vector
populations. However, it is hoped that well qualified and trained personnel are now
available to contribute to the evaluation of current attack measures including the
application of age-grading techniques in areas of persisting malaria transmission in
Morocco, Syria and Turkey.

Only records of sporozoite rates of all species are old with the exception of claviger
in Syria (Muir & Keilany, 1972) and pharoensis and sergentii in Faiyum, Egypt (El Said et
al., 1986). Therefore, it would be highly desirable to combine age-grading of vector
populations with gland dissections in the same countries mentioned above and extend this
work to sergentii and multicolor in the Algerian oases of the Sahara. In these countries,
it may be worth trying the new techniques for detection of sporozoites in mosquitoes in
addition to classical gland dissections (see VOL. I, under 2.9). It would also be useful
to conduct trials of the new techniques in Egypt in the Nile Delta where
seroepidemiological surveys may reveal the presence of cryptic foci of transmission, and to
compare one of these techniques with the classical method of dissection in Faiyum
governorate where transmission is taking place on a larger scale.

No new records of insecticide resistance in potential or active vectors in the
Mediterranean Basin subsequent to those listed by the Expert Committee reports (WHO, 1980 &
1986) except a few tests indicating a low level of resistance to permethrin in sacharovi in
a few localities in Syria. This requires confirmation as explained below. According to
information compiled in the last Expert Committee report (WHO, 1986), cases of insecticide
resistance which created practical implications that necessitated a change in control
operations, are DDT resistance in maculipennis in the USSR, DDT resistance in pharoensis
and DDT resistance in sergentii in Egypt. The last case still awaits confirmation. The
biochemical basis of OP and carbamate resistance in pharoensis still awaits investigation.
A good example of cooperation between agricultural and health authorities comes from Algeria whereby the use of DDT in agriculture was progressively reduced. This seems to have stabilized the level of DDT resistance in labraichiae, hence conserving the effective use of DDT for malaria control (Ramsdale, 1975).

A notable contribution to the epidemiology and control of malaria has been provided from the experience of countries of the Mediterranean Basin. As in all continental Europe, malaria eradication has been maintained in countries of the European Mediterranean, but there receptive areas remained more vulnerable to the implications of imported malaria resulting in some episodes of reintroduction of malaria transmission as observed in Corsica, France in 1970-1971, Greece in 1975-1977, and the southern areas of the USSR in 1980-1982 [see SECTION I, under 1.1 and under 1.2.1(4)].

In contrast, malaria eradication in the Asian part of Turkey after having resulted in almost complete elimination of malaria transmission by the late 1960's, the malaria situation deteriorated for several reasons and culminated in a severe epidemic that broke out in 1976-1977. An attempt was made to describe retrospectively the factors related to the malaria parasite, the vectors and human ecology that contributed to the deterioration of the malaria situation (Ramsdale & Haas, 1978). The success of control measures and reinforced surveillance activities in containing the epidemic in Chukurova/Amikovasi was theoretically evaluated (Onori & Grab, 1980). The evolution of the epidemic could have been forecasted and early preventive action taken to curtail it, if longitudinal data of entomological factors were available. Subsequent to the epidemic and in recent years several studies have been conducted on vector bionomics in relation to malaria transmission in Chukurova area (Prof. H. Kasap, personal communication, January 1990, and reference list of Turkey). Although the malaria situation has greatly improved in recent years under attack measures and surveillance activities adopted as indicated from the total number of cases (20 134) recorded in 1987 (see Table 20), representing about 36% of that recorded in 1984, still the number of indigenous cases was high (12 668) of which 96% came from Strata Ia and Ib (see Fig. 7). Regarding the implications of water resources projects to the malaria situation, useful information has been provided on Seyhan irrigation project in Adana plain (Giglioli, 1979 and Lassen, 1982). Of the major problems encountered is the growth of horizontal and emergent vegetation in man-made water reservoirs of the agro-hydroelectrical project of Adana. Attempts to cut vegetation failed because it grew again in a few weeks causing great pullulation of sacharovi, and consequently malaria cases increased in the district around the artificial lake. Temephos larvidcing using a row boat gave satisfactory reduction in larval density, and subsequently the malaria cases around the lake decreased. The main source of breeding of sacharovi is the network of earth drainage canals with their overgrown condition. Although measures to clear the drains are attempted, vegetation returns in less than two months. It has been suggested that the drainage canals be lined with concrete. Although the capital cost seems to be high, it would be more rewarding in the long run than the cost of the current maintenance of drains besides the expenditure of vector control (Giglioli, 1979). Recent information obtained in 1984 indicated that there are no plans to improve the drainage system as this is considered excessively costly (Gratz, 1987). This undoubtedly remains an obstacle facing the goal of interruption of malaria transmission in Turkey unless sufficient financial resources are sought. Another adverse factor is the problem of seasonal workers which remains outstanding unless reinforcement of surveillance and treatment activities are rigorously implemented. In 1982, health services in Turkey were passing through a transitional period involving the integration of vertical services into a horizontal system of PHC for which training was regarded as top priority. It is hoped that this has materialized by now and that involvement of the community in malaria vector control at least by adopting self-help methods has been initiated and encouraged. The shortage of qualified entomologists for malaria control has been noted. It is hoped that a sufficient number of entomologists with the appropriate training would be assigned to update the knowledge on vector seasonal prevalence, vector density in relation to man, degree of anthropophily and exophily as well as determination of vector longevity particularly in Chukurova/Amikovasi area in order to contribute effectively to the epidemiological evaluation of attack measures. Monitoring of susceptibility of sacharovi to malathion where it is acceptable to the population and to pirimiphos-methyl where it is being applied is essential.

Adjacent to Turkey, malaria transmission persisted in certain foci in Syria but on a much smaller scale. In these foci, sacharovi is also the main vector associated in some
areas with *supergilictus* as an additional vector. According to the most recent information provided in 1987, the persisting foci are situated in the areas of Malkiya on the Dejla river along the northeastern border with Turkey, Aleppo and Lattakia. Additionally, sporadic cases were recorded in Tartous, Hama and Raqqa. Because of the high rate of refusal of the inhabitants to spray their houses with malathion, this insecticide was replaced by permethrin with satisfactory results. Yet some field tests indicated the presence of low level resistance to permethrin in *sacharovi* in certain localities in Hama and Aleppo provinces. The extent of this resistance in areas under permethrin spraying in Syria has to be delimited and final confirmation should be sought by sending egg batches of survivors of the discriminating dosage to recognized laboratories. If confirmed, thorough entomological/parasitological observations should be conducted to determine the operational implications of this resistance. On water resources projects in Syria, no information is available on the malaria situation in areas under the influence of dams. However, general observations indicated that marshes and swamps are formed in the vicinity of several water sources such as springs and shallow wells. Poor maintenance of irrigation canals and drains with the consequent growth of vegetation, as well as the erosion of banks slow down the flow, thus providing favourable breeding sites for *sacharovi* (Eshghy, 1986). In the Ghab valley, Hama province, which has been the source of intense malaria transmission with an epidemic episode in 1980, the river El-Assi remains a meandering channel forming overgrown pockets with its overflow creating swamps suitable for intense breeding of *sacharovi*. It is hoped that the planned design for this river envisaged in 1986-1990 5-year plan will remedy this situation. Moreover, filling in ponds and pools in Raqqa and Der El-Zor was also advocated for permanent elimination of vector and snail breeding (Sadek, 1986). In Syria as well as in Turkey, environmental management should be the backbone of an integrated malaria vector control combining cost-effective and safe methods, and seeking multisectoral cooperation. It is hoped that the financial and administrative problems, particularly those which arose from decentralizing the malaria service to be administered by provincial health institutions, have now been solved. As in Turkey, the whole gamut of vector bionomics in Syria awaits updating including determination of vector longevity in sprayed and unsprayed areas.

Of countries of North Africa, Tunisia and Libya succeeded in eliminating malaria transmission completely with the exception of a small outbreak of 18 cases of *P. vivax* that occurred in Libya in September-October 1980 in a coastal town west of Tripoli. The outbreak was thought to have originated from immigrants, eight of whom were found infected, and the remaining cases were Libyan residents who never travelled outside Libya. No vector could be found, although *labranchiae* used to exist in Tripolitania up to Tauerga, which seems to be the easternmost limit of its distribution in the southern shores of the Mediterranean (Macdonald, 1982). Although the outbreak was successfully extinguished, and no more indigenous cases have been recorded elsewhere in Libya, there is a need for updating the receptivity of different areas particularly those which are vulnerable to an influx of immigrants from malariaious countries (Gebreel, Gilles & Prescott, 1985).

Of other countries of North Africa, Morocco in 1987 is still recording autochthonous cases in foci distributed in five provinces, and additionally resumption of transmission has been encountered in three old foci (Khouribga, Fès and Meknès). While there has been some improvement in some provinces represented by a reduction in the number of autochthonous cases amounting to 20-75%, the total number of cases in 1987 increased by 49% compared with 1986. It should be noted that the number of imported cases reached over 600 compared with 97 in 1986. Most of the foci occur in the northern half of the country where *labranchiae* is the main vector, but there has been no recent entomological information to indicate the impact of current attack measures on the vector population in these foci, and this represents an important gap in knowledge of epidemiological relevance.

In Algeria, where large areas have been under the maintenance phase particularly in the northern part of the country, only nine indigenous cases were recorded sporadically in 1987 (6 in 6 Wilayat in the maintenance phase of which 2 were *P. falciparum*, and 3 in the southern oases under reinforced malaria control). It is well known that *labranchiae* acts as the major vector in the north, and *sergentii* is the main vector in the southern oases. It has been suggested that specific laboratory studies should be undertaken to ascertain the identity of *sergentii* s.l. Whether *sergentii sergentii*, the important vector of malaria exists in the Algerian oases or is associated with *sergentii macmahoni* which has no epidemiological importance. The separation of the two taxa by morphological characters is rather difficult because of intergradation. Also, the situation of *multicolor* which exists
in several oases of North Africa in association with *sergentii* remains dubious. Although it has been successfully infected experimentally in Egypt, it has never been incriminated in nature except on epidemiological grounds. Even this has been debated, and therefore its situation needs to be clarified by systematic dissections aided by the application of the new techniques when foci of transmission exist.

All countries of North Africa which have achieved malaria eradication or are progressing towards this goal are threatened by importation of malaria whether through immigrants or foreign visitors or nationals travelling to malaria endemic countries. Measures recommended by WHO-sponsored meetings and conferences dealing with the problem of imported malaria should also apply to countries of North Africa (see SECTION I, under 1.2.2). In fact, Algeria, Morocco and Tunisia participated in the coordination meeting that was held in Erice, Italy in October 1979 on the prevention of reintroduction of malaria in countries of the west Mediterranean (WHO 1979b).

Information on malaria in water resources projects in countries of North Africa is limited; only the situation in the area of one dam in Morocco was described at the initial stages of its construction in the early 1970's. On the other hand, the construction of the trans-Saharan highway extending over a distance of about 6000 km to connect Lagos and other areas of West Africa with the Mediterranean shores, is an important undertaking due to its close relation to socioeconomic development. The risks arising from this highway to the malaria situation in North Africa have been thoroughly discussed by several authors (Ramsdale & Zulueta, 1983; Benzerroug & Jansens, 1985; Chauvet, Hassani & Izri, 1985; and Bruce-Chwatt, 1986). With increasing travel, there is a great likelihood of introduction of *P. falciparum* carriers among the influx of people coming from West Africa. This constitutes a real danger for the southern oases of Algeria where *sergentii* and multicolor abound, since epidemics of falciparum malaria were witnessed in the recent past as in the oases of Tassili N'Ajjer (Léfevre-Witier, 1968) where the source of infection was most probably of African origin. For the north, where labranchiae prevails, some authors minimized the risk of introduction of *P. falciparum* from West Africa, extrapolating from the experimental evidence indicating that European members of the An. maculipennis complex proved to be refractory to *P. falciparum* of African origin. It would be extremely useful to repeat the experiments using labranchiae from North Africa and strains of *P. falciparum* from West Africa. The other risk lies in the possible spread of An. arabiensis and/or An. gambiae s.s. with the increasing number of air-conditioned vehicles crossing the highway in less than 24 hours. The lessons of past invasion of Brazil and Egypt were given as a reminder for increasing the awareness of this potential danger in North Africa. There is a consensus that with the increase in freshwater supply for agricultural and industrial development projects, as well as the planned expansion of rice cultivation in several countries of north Africa, the two African vectors will have better chances for colonizing the oases of the Sahara. Greater vigilance on vectors and strengthening preventive and control measures including dissection of vehicles at frontier posts in Algeria have been advocated. On the human side, the measures recommended for dealing with imported malaria should be strengthened and applied to travellers from West Africa. It was even suggested that migrant populations should be screened for malaria and treated at frontier areas before they proceed to the north through the highway (Chauvet, Hassani & Izri, 1985).

Seroepidemiological studies by IFA test proved to be a useful tool for providing complementing evidence on the disappearance of malaria transmission as was shown in former foci in northern Algeria (Benzerroug & Wéry, 1985), and by longitudinal studies in Tunisia (Ambroise-Thomas et al., 1976), or in screening immigrants in Libya (Gebreel, Gilles & Prescott, 1985). Thus, the IFA test may be a valid tool for identifying asymptomatic parasite carriers [difficult to detect microscopically]. This screening process can, therefore, be recommended in countries which host large groups of immigrants, particularly those coming from areas where *P. falciparum* chloroquine resistance is present (WHO, 1985).

In Egypt, according to the available information, the number of cases detected steadily decreased in the last decade reaching an insignificant level (194 in 1984, 72 in 1985 and 63 in 1986). This situation is puzzling bearing in mind the very large population at risk (13 million) and that in two villages in Faiyum governorate there were 23 cases of P. vivax and 51 cases of P. falciparum in 1983 (El Said et al., 1986). Seroepidemiological surveys carried out during 1977-1979 (Hassan et al., 1983) could help in clarifying the anomaly of the malaria situation in Egypt. In the Nile Delta, where pharoensis the principal vector prevails, malaria transmission occurs in hidden foci that can remain undetected. This condition was thought to be due to a combination of factors, viz: distribution of antimalarial drugs which depresses the parasitaemia to a submicroscopical level, and rotation between rice and cotton cultivation every two years, as well as irregular application of pesticides in agriculture. The last two factors produce variation in vector density from year to year and from one place to another. In contrast, transmission in Faiyum where pharoensis is joined by sergentii is perennial and at a much higher rate. Yet variation has been observed between villages depending on the relative abundance of the two vectors (El Said et al., 1986). Since parasitological examination under conditions prevailing in the Delta would be extremely inadequate, it has been suggested (Hassan et al., 1983) that a serological survey be carried out once a year, covering children of 5-9 years age-group.

No information has been provided on imported malaria in Egypt despite the increasing travel to and from malaria endemic countries involving also Egyptian nationals. Bearing in mind that in Egypt malaria became a notifiable disease as early as 1930 (Halawani & Shawarby, 1957), enquiry about records of imported malaria should be made.

A good background knowledge has been provided on the distribution of malaria vectors and the malaria situation in Sinai, Egypt. Since this has been done more than 30 years ago, it is time to update this knowledge under the present ecological conditions, on the basis of which the appropriate malaria control measures can be planned if warranted.

The history of the gambiaca invasion in Egypt and the campaign of its eradication 1942-1946 has been well documented (Shousha, 1948). It seems that the joint measures undertaken by the Sudanese and Egyptian governments have halted the northward spread of arabiensis, the member of the An. gambiae complex occurring in northern Sudan. The latest information on the results of joint inspection surveys comes from reports provided up to 1987. Therefore, more recent reports should be sought, particularly after the unusual floods that affected the Sudan in 1988.

In the Mediterranean Basin, no information could be traced on integrated malaria vector control, nor on community participation. Therefore, it is time that active steps be taken to set trial and demonstration areas for integrated control in each country where malaria transmission persists and current control measures are showing slow progress. In these areas, communities should be stimulated and motivated to actively participate in control activities by undertaking, for example, simple source reduction, culturing and distribution of larvivorous fish and the use of impregnated bed-nets that proved to be effective, economical and safe. It is necessary also to seek information on the role of PHC in malaria vector control, and find solutions to the outstanding problems experienced so far.
SECTION III(A) THE MEDITERRANEAN BASIN

The references of Subsection(i) VECTOR BIOLOGICAL AND SUBSECTION(ii) EPIDEMIOLOGY AND CONTROL OF MALARIA are arranged by country in alphabetical order. References dealing with more than one country or more than one vector are listed first under GENERAL. Some authors cited previous references dealing with the same subject. These are marked in the margin with letter c. References cited by authors but not seen in the original are marked in the margin with an asterisk. To avoid repetition, for certain references readers are referred to previous reference lists of SECTIONS I and II or ANNEX 1 of the present issue, or the reference lists shown in VOL. I.

GENERAL


Detinova, T.S. (1962)


Garrett-Jones, C. (1964b)

c Garrett-Jones, C. & Grab, B. (1964)


Horsfall, W.R. (1955)

c Macdonald, G. (1957)


c Mattingly P.F. & Knight, K.L. (1956)


ALGERIA


Gillies, M.T. & de Meillon, B. (1968) - see under GENERAL above.


Senevet, G. & Andarelli, L. (1956) - see under GENERAL above.


World Health Organization (1979b) - see reference list of SECTION I, 1.2.2.


** BULGARIA **


** CYPRUS **


World Health Organization (1979) - see under GENERAL above.


** EGYPT **


Davidson, G. (1955) — see under GENERAL above.

Detinova, T.S. (1962)


Farid, M.A. (1956) — see under GENERAL above.


Garrett-Jones, C. (1964a) - see under GENERAL above.

Garrett-Jones, C. (1964b)


Macdonald, G. (1957)^1

Macdonald, G. & Gackel, C.W. (1964) — see under GENERAL above.


Report of the annual joint inspection mission to the *gambiae* control project in Egypt and Sudan for 1987, during the period 14 September-18 October 1987 [In Arabic].


Zahar, A.R. (1974) - see under GENERAL above.


FRANCE


GREECE


ISRAEL


Gramiccia, G. (1956) - see under GENERAL above.


ITALY


Bettini, S. et al. (1978) – see reference list of SECTION I, under 1.2.1(i).


* c Celli, A. (1934) La malaria, Torino, UTET [In Italian].


Detinova, T.S. (1962)

c Gillies, M.T. (1956) – see under GENERAL above.


* c Pampana, E. (1944) Epidemiologia della malaria, Rome, Editrice Nazionale [In Italian].


Senior-White, R.A. (1954) — see under GENERAL above.


**JORDAN**


Farid, M.A. (1956) — see under GENERAL above.


Zulueta, J. de & Muir, D.A. (1972) — see under GENERAL above.

**LEBANON**


Gramiccia, G. (1956) — see under GENERAL above.


World Health Organization (1979) — see under GENERAL above.

Zulueta, J. de & Muir, D.A. (1972) — see under GENERAL above.

**LIBYA**

Detinova, T.S. (1962)


* Kadiki, O. & Ashraf, M. (1972) Malaria in the Libyan Arab Republic. Department of Endemic Diseases, Ministry of Health, Tripoli, Libya. [Seen only in an abstract in TDB by Prof. L.J. Bruce-Chwatt as shown in the text.]


World Health Organization (1979) — see under GENERAL above.


MOROCCO


Detinova, T.S. (1962)


World Health Organization (1979) - see under GENERAL above.

ROMANIA


SPAIN

Blázquez, J. & Zulueta, J. de (1980) - see reference list of SECTION I under 1.2.1(i).

SYRIA

boyd, M.R. (1949)  


Garrett-Jones, C. & Grab, B. (1964)


World Health Organization (1979) – see under GENERAL above.


Zulueta, J. de & Muir, D.- (1972) – see under GENERAL above.
TUNISIA


TURKEY


Detinova, T.S. (1962)


Kasap, H. et al. (1990?) Residual efficacy of pirimiphos-methyl (Actellic) on Anopheles sacharovi in Çukurova, Turkey. (submitted to Medical & Veterinary Entomology).


c Livadas, G.A. & Sphangos, G.C. (1941) - see under GREECE above.

c Macdonald, G. (1957)1


c Moshkovsky, S.D. (1946) - see under GENERAL above.

Muench, H. (1959) - see under GENERAL above.


c Ramsdale, C.D. (1975) - see reference list of VOL. 1, under 2.6.2, p. 213.


* c Tekinel, O. et al. (1975) Ground water status in the Lower Seyhan Plain Irrigation Project Area and anticipated problems. Çukurova Univ. Ziraat Faak, Yilligi. 6:179-194.


USSR


Detinova, T.S. (1962)

ibid. Collected Lectures 2:227-249.

Timofeeva, L.V. (1980) Impact of hydraulic engineering projects and irrigation schemes on change of malarialene situation and measures to prevent its deterioration.
ibid. Collected Lectures 2:72-93.


YUGOSLAVIA


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1. See reference list of PREFACE in VOL. I, pp. 11-12.
2. See reference list in ANNEX 1 in the present issue.
ANNEX 1

SELECTED REFERENCES ON MALARIA

QUANTITATIVE EPIDEMIOLOGY

Charles Griffin & Co. Ltd.


* Moskovskij, S.D. (1950) The main laws governing the epidemiology of malaria. Moscow. [In Russian]. (Seen by title only).


ANNEX 2

ABBREVIATIONS

**Entomological**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSC</td>
<td>Pyrethrum spray collection</td>
</tr>
<tr>
<td>ETC</td>
<td>Exit-trap collection</td>
</tr>
<tr>
<td>UF</td>
<td>Unfed females</td>
</tr>
<tr>
<td>F</td>
<td>Fed or fully engorged females</td>
</tr>
<tr>
<td>HG</td>
<td>Half-gravid females</td>
</tr>
<tr>
<td>G</td>
<td>Gravid females</td>
</tr>
<tr>
<td>HBI</td>
<td>Human blood index</td>
</tr>
<tr>
<td>EIR</td>
<td>Entomological inoculation rate</td>
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</table>

**Parasitological & others**

<table>
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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>ABER</td>
<td>Annual blood examination rate</td>
</tr>
<tr>
<td>API</td>
<td>Annual parasite incidence</td>
</tr>
<tr>
<td>SPR</td>
<td>Slide positivity rate</td>
</tr>
<tr>
<td>PR</td>
<td>Parasite rate</td>
</tr>
<tr>
<td>PHC</td>
<td>Primary Health Care</td>
</tr>
<tr>
<td>RH</td>
<td>Relative humidity</td>
</tr>
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