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Malaria vectors in European Russia

Marina I. Sokolova[1] and Keith R. Snow[2]
[1] Science & Information Department, Vavilov Institute of General Genetics, Russian Academy of Sciences, Gubkin str. 3, 119991 Moscow, Russia. E-mail: msokolova@vigg.ru [2] School of Biosciences, University of East London, Romford Road, London E15 4LZ, UK E-mail: k.r.snow@uel.ac.uk

Abstract

The malaria vectors of European Russia are reviewed and the status of vector species in transmitting malaria in Russia is discussed.

Malaria in Russia in the 20th century

In 1946-1948 there were 1500-2000 cases of malaria per 10,000 of the population in the territories of the former USSR, including the Moscow region. Following the introduction of DDT for malaria control in 1945 the number of cases in the USSR was markedly reduced. In 1960 the Ministry of Public Health of the USSR announced the start of a campaign to eradicate malaria from the country. This was achieved mainly by administration of curative treatment to all malaria patients in order to eliminate the parasite reservoir. However, since 1966 the number of imported cases of malaria has increased and has led to renewed local transmission. Cases of local malaria now outnumber imported cases in the European Russia. During the year 2000 a total of 763 cases of malaria were registered in the Russian Federation, 47 of which were autochthonous (WHO, 2001).

Of the three species of malarial parasites recorded in Russia, *Plasmodium vivax* has always been and remains the most widely distributed. However, disease caused by the tropical *Plasmodium falciparum* was also present, with rare epidemics recorded in central and northern Russia and with serious foci in the Volga Region (Bruce-Chwatt & de Zulueta, 1980). Individual cases of autochthonous quartian malaria caused by *Plasmodium malaria,* were recorded in central and northern parts of Russia, but were more common in the south of the country. The fourth human malarial parasite, *Plasmodium ovale*, was recorded only in visitors from Africa, and local cases of infection with this species have never been reported.

In European Russia the transmission of *P. vivax* occurred up to latitude 64 ° N. Cases of malaria caused by *P. falciparum* are seldom found at such high latitudes; a rare example occurred in the Vologda and Arkhangelsk regions in 1936, when exceptionally high summer temperature of up to 35°C were recorded. The last locally transmitted cases of *P. falciparum* malaria in Russia were in 1962.

Malaria vectors in Russia

Although the first Russian record of a malarial mosquito (as *Anopheles bifurcatus*) was made in 1813 (Porchinskii, 1911) and the forerunner of the Institute of Medical Parasitology and Tropical Medicine was established by Martsinovsky in 1920, it was not until the period between 1940 and 1960 that Beklemishev and his colleagues developed the foundation of modern medical entomology in Russia. In particular the monograph by Beklemishev (1944), dealing with *Anopheles maculipennis*, was a significant landmark in the understanding of this taxon.

From 1970, and for several further decades, the standard work used for the identification of mosquito species in the USSR was the monograph by A.V. Gutsevich, A.S. Monchadsky, and A.A. Shtakelberg entitled *Mosquitoes. Family Culicidae*, published in the Fauna of USSR series by the Academy of Sciences of USSR. Gutsevich *et al.* (1970), following Beklemishev (1944), considered *An. maculipennis* to be a single, polytypic species with six Palaearctic subspecies: *maculipennis s.s., messeae, melanoon* (including the *subalpinus* form), *labranchiae*, *atroparvus*, and *sacharovi*. Of these only the subspecies *labranchiae* was considered to absent from Russia.

General acceptance that the individual members of the Maculipennis Complex are separate species came later (Artemiev, 1984), mostly with the work of Stegnii and collaborators (Stegnii, 1976, 1991; Stegnii & Kabanova, 1976; Stegnii *et al.*, 1973). This work includes the chromosomal differentiation of *An. maculipennis* and *Anopheles beklemishevi* and led to the systematic re-appraisal of the *An. maculipennis* complex by White (1978).

Of currently recognised Palaearctic species of the Maculipennis Complex, only *An. labranchiae* and *An. martinius* have not been recorded in Russia. On the evidence of reproductive isolation between sympatric populations, *melanoon* and *subalpinus*, treated as synonyms by Gutsevich *et al.* (1970), were considered to be separate species by Cianchi *et al.* (1987). However, Stegnii (1991, 1993) reiterated his view that *melanoon* and *subalpinus* were conspecific. Having reviewed the available evidence, Y.-M. Linton and R.E. Harbach (personal communication, 2002) intend to formally synonymise *subalpinus* Hackett & Lewis, 1935 with *melanoon* Hackett, 1934, pointing out that it is apparent that *An. subalpinus* and *An. melanoon* represent a single species which has polymorphic eggs. They are currently undertaking a morphological and molecular study in their laboratory to characterise *An. melanoon* and provide reliable diagnostic characters to differentiate this species from others of the *An. maculipennis* complex.

Also the presence of *Anopheles (Anopheles) sinensis* Wiedemann, 1828 has been revealed in Russia. According to Gordeev (1997), *An. sinensis* was wrongly identified as *An. hyrcanus* in the basin of the river Zeya (Stanovoy Province of eastern Siberia), and is, he believes, the sole malaria vector in that region. The eastern limits of the distribution of *An. hyrcanus* are not known, but may not extend into eastern Siberia; *An. sinensis* has a wide, imprecisely delimited, Oriental and eastern Palaearctic distribution and is a confirmed vector of malaria in Japan, Korea and northern China (Ramsdale, 2001).

For the European part of Russia (west of the Ural Mountains), Gornostaeva (2000) lists 12 *Anopheles* species: *algeriensis, atroparvus, beklemishevi, claviger, hyrcanus, maculipennis, melanoon, messeae, plumbeus, sacharovi, subalpinus* and *superpictus*. This listing will require modification when the synonomy of *An. subalpinus* with *An. melanoon* is formally proposed.

Epidemiological efficacy of malaria vectors

Beklemishev (1944) and Derbeneva-Ukhova (1974) listed eight major factors that determine epidemiological efficacy of malaria vectors in Russia:

- susceptibility of mosquitoes to *Plasmodium* parasites
- sporozoite survival in salivary glands
- female feeding behaviour
- absolute and relative number of mosquitoes
- seasonal dynamics of mosquito densities
- survival rate and infective period of mosquito females
- ambient temperature
- winter diapause of adult females in a state of gonotrophic dissociation.

The presence and abundance of oocysts and sporozoites in a female mosquito indicate its susceptibility to *Plasmodium* species. Specimens of *An. maculipennis* s.l. captured in the wild have been experimentally infected with three different *Plasmodium* species each of which develops as different rates (Nikolaev, 1935, cited by Sergiev & Yakusheva, 1956). When maintained at 25°C, it was found that development to the sporozoite stage of *P. vivax* required 10 days, of *P. falciparum* 12 days and of *P. malariae* 16 days. When these experiments were repeated with wild caught *An. maculipennis* s.l. fed on hospital patients infected with *P. falciparum* in Solvychegods (61°N) (Yakusheva, 1939, cited by Sergiev & Yakusheva, 1956), the mosquitoes became infected even when patients had a low level of blood gametocytes.

However, the European strains of *P. falciparum* used in malaria therapy experiments disappeared during the European Malaria Eradication Programmes. Moreover mosquitoes of the Maculipennis Complex in European Russia and elsewhere in Europe seem to be refractory to infection with extant strains of this parasite (de Zulueta *et al.*, 1975; Dashkova & Rosnicyn, 1982).

Artemiev (1984) reported that *An. superpictus* and the non-European *An. pulcherrimus* have both been found to be susceptible to *P. falciparum,* where *An. hyrcanus* is more resistant. Apparently the majority of *Anopheles* species in Russia is susceptible to *P. vivax*. However comparative experiments conducted under controlled conditions have not been carried out (Artemiev, 1984). In the 1970s, Derbeneva-Ukhova (1974) reported that a high percentage of *An. maculipennis* s.l., *An. superpictus, An. claviger* and *An. plumbeus* could be infected with both *P. vivax*, and *P. falciparum*, while the percentage infection with *An. hyrcanus* and *An. pulcherrimus* was lower. However, those experiments should be repeated using modern experimental techniques.

The duration of sporozoite infection in the salivary glands has, apparently, been little investigated in natural Russian populations. It is known that in Uzbekistan, sporozoites of *P. falciparum* survive in hibernating females of *An. sacharovi* at winter ambient temperature above freezing. Such mosquitoes are, therefore, epidemiologically important throughout the year (Shishlyaeva-Matova, 1952).

The degree of exophily, endophily, exophagy and endophagy and levels of anthropophily are important factors in assessing the intensity of malaria transmission. Female behaviour can be complex, as, for example, with *An. plumbeus* which often feeds on people inside houses (endophagy) but always rests out-of-doors during the day (exophily) (Artemiev, 1984). The extent of feeding on human blood by more or less endophilic species of the *Anopheles maculipennis* complex or *An. superpictus,* or the more exophilic and exophagic *An. claviger, An. hyrcanus* s.l. (and in countries bordering southern Russia of *An. pulcherrimus*), all of which also feed on other mammals, depends to varying degrees on relative availability and other local conditions.

The predominant species is likely to be major malaria vector if inter-relationship with humans, and physical conditions permit. In the district of Solnechnogorsk (Moscow Region) there was an incidence of about 2000 malaria cases per 10,000 of the population in the mid-1940s. At this time the density of female *An. messeae* was around 2,000 per shed. Buildings in this district were sprayed with DDT from 1949 onwards and by 1953 densities had fallen to 3-10 females per shed. In 1959 transmission had ceased and malaria eradication in this region appeared to have been achieved. DDT spraying ceased in 1960. However, by 1977 increasing densities of *An. messeae* in the region has reached the level of the 1940s (Sokolova & Volegova, 1980). The Moscow Region should, therefore, because of high levels of importation of malaria and migration of malaria carriers from the south, be considered as a focus at risk of renewed malaria transmission, a situation susceptible to intensification by climate warming.

The period required for the development of *Plasmodium* in mosquitoes at the prevailing range of temperature has been determined experimentally for each malarious zone in Russia, as has the time required for egg development following a blood meal. Ageing mosquitoes by examination of the ovaries has facilitated the gathering of information on the life expectancy of anopheline vectors; a method pioneered by Polovodova (1949). However, it is important to note that when the method of assessing the physiological age of mosquitoes was fully developed (Detinova, 1962), malaria had already been eradicated from most parts of the former USSR, and only local foci in Dagestan, Central Asia and Azerbaijan persisted. Therefore experimental data were obtained from laboratory cultures of mosquitoes. It would appear that consequential estimations of physiological age assessed by the number of ovipositions (using the number of ovariole dilatations) was overestimated in the 1960s and 1970s. For example, around the Istra River reservoir in Moscow region, *An. messeae* females, captured in a shed, where the access to cows was practically unlimited, oviposited 1-2 times (Sokolova, unpublished). However, according to the data of Detinova (1962), at the end of May, August and September the majority of *An. messeae* females were multiparous, with 3 and more dilatations. Sokolova (1995) also examined females of *An. messeae* from rice farms in the Krasnodar Region in the summer of 1981. This area is considerably south of the Moscow Region. The largest group of mosquitoes was found to be 2-parous, with only half as many 3-parous females present. Detinova (1962) found the same pattern for Moldova, where the climate is much milder than that of the Moscow region.

Many studies have been performed on age-grading of mosquitoes in Russia and the former USSR and there are many reports on methods employed and population studies e.g. Detinova (1962), Sokolova (1982, 1994a, 1994b, 1995), Sokolova & Smirnov (1985), WHO (1999). Of the methods available, retrospective analysis of reproductive age of female mosquitoes (Sokolova, 1994, 1995; Sokolova & Smirnov, 1985) provides comprehensive information on the reproductive profiles of populations.

The ambient temperature and the duration of periods of warm weather determine whether or not *Plasmodium* is able to develop within the vector species. *An. messeae* is a poor vector in the northern part of Russia largely because of the low ambient temperature. However, there have been times when the temperature in the north was high and malaria transmission could occur, as for instance in 1936, when the temperature reached 35°C in Arkhangelsk (Sergiev & Yakusheva, 1956).

Hibernation of female *An. atroparvus* in a state of gonotrophic dissociation has been well researched in Europe. Similar behaviour is indicated in *An. maculipennis* in Georgia, where these mosquitoes were responsible for winter cases of malaria (Kalandadze & Lemmer, 1957, cited by Soprunov & Khromov, 1988). In southern parts of Russia, when ambient temperature permits, it is also possible for such mosquitoes to be responsible for the transmission of autochthonous malaria.

Malarious zones in European Russia

The following four malarious zones may be recognised in European Russia:

I Mid and south taiga

Vectors: *An. messeae, An. maculipennis* and *An. beklemishevi.*

Two, less often, three generations of mosquitoes occur per year. The duration of sporogony of *P. vivax* is 38-53 days.

II Deciduous-coniferous woodlands

Vectors: *An. messeae, An. maculipennis, An. beklemishevi, An. atroparvus* and *An. claviger.*

Three to four generations occur each year. The duration of sporogony of *P. vivax* is 29-37 days.

III Deciduous forests

Vectors: *An. messeae, An. maculipennis, An. atroparvus, An. claviger and An. plumbeus.*

Four generations occur each year. The duration of sporogony of *P. vivax* is 24-29 days.

IV Steppe zones and southern areas

Vectors: *An. messeae, An. maculipennis, An. atroparvus, An. claviger, An. plumbeus, An. hyrcanus* s.l. and *An. sacharovi.*

Five generations occur each year. The duration of sporogony of *P. vivax* is 17-19 days and hence malaria epidemics are possible.

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Just published

A CD-ROM is now available entitled *The Mosquitoes of Europe*. This has been prepared jointly by teams at the Laboratoire/Cellule Entomologie, EID Mediterranee, France and the Laboratoire de Morphotaxonomie des Vecteurs, IRD, Montpellier, France, with the assistance of colleagues throughout Europe. This CD-ROM will be helpful to all entomologists involved in the study and control of mosquitoes in Europe, and to researchers and teachers of biology and wetland ecology. It contains information on the morphology, ecology and distribution of the mosquitoes of Europe with more than 800 original illustrations and photographs, and access to a knowledge base on their taxonomy, bio-ecology, distribution, medical and veterinary importance, and control. An indexed bibliography of 325 references is included.

In contrast to dichotomy keys, the identification software allows identification using a number of criteria. At each step, the user selects a morphological, ecological or distributional criterion. The user progresses towards the identification of the species by successive choices suggested by images. At the end of the process, taxonomic cards allow the result to be checked and compared with closely related species. The CD-ROM allows the identification of one hundred mosquito species, covering thirty-seven European countries plus Madeira. Belarus, Cyprus, Moldova, Turkey, Russia and Ukraine are not included. This bilingual CD-ROM (English/French) includes all species reported from Europe with the exception of two species present only in Russia.

The CD-ROM (PC compatible) is available at a cost of 54.35 Euros (plus 7 Euros postage). Enquiries to: Francis Schaffner, Laboratoire/ Cellule Entomologie, EID Méditerranée, 165 av. Paul Rimbaud, F-34184 Montpellier cedex 4. Email: fschaffner@eid-med.org