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The vectorial capacity of *Anopheles sacharovi* in the malaria endemic area of Şanlıurfa, Turkey

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Abstract

Surveys were conducted in four selected villages in the malaria endemic area of Şanlıurfa, southeastern Turkey to evaluate the transmission potential of malaria using the concept of vectorial capacity (VC). Precipitin tests demonstrated no significant difference in the host preferences of *An. sacharovi* in the selected villages (χ^2= 2.649; P > 0.05). However, the human blood index was estimated to be 19.5% (n = 416) from both the house and animal shed catches, whereas the animal blood index was 74.8% (n = 163) from the house catches. The high animal blood index from the house catches was probably due to the proximity of human settlements and animal sheds. Addition to these variables, the duration of the gonotrophic and the sporogonic cycles of *Plasmodium vivax*, and the probability of daily survival of mosquitoes were also estimated in order to calculate VC. The VC was 0.22 on average. It is suggested that the low VC value may be due to the low human blood index. Because of the increasing trend in temperature in the region, it is possible that there may be an increase in the VC in near future.

Keywords: *Anopheles sacharovi*, vectorial capacity, human blood index, Turkey, malaria

Introduction

Anopheles sacharovi Favre is the major vector of *Plasmodium vivax* and the cause of malaria transmission in Turkey (Kasap *et al.*, 2000; Kuhn *et al.*, 2002). Malaria is still one of the most important vector-borne diseases in Turkey (Kasap *et al.*, 2000; Alten *et al.*, 2003), especially in the south-eastern part of Turkey (Kasap *et al*., 2000; Gratz, 2000; WHO, 2000). The importance of this region in relation to malaria is due to lower socioeconomic conditions, the importation of malaria by migrant workers, and a new irrigation network project, The South-eastern Anatolian Project (Güneydoğu Anadolu Projesi = GAP) (Özer *et al*., 2001). The large size of irrigation activities in the GAP region could possibly affect the temperature and rainfall trends (GAP, 2003). Since mosquitoes have a high sensitivity to climatic factors; these may influence the size of mosquito populations, mosquito activity and biting rates, and also the extrinsic incubation period of the parasite (Epstein *et al*., 1998). However, climate alone is not a sufficient factor for the spread of malaria. If mosquito breeding is not adequately controlled and infected humans are neither diagnosed nor treated due to an inadequate medical infrastructure, then malaria will not be reduced (Hunter, 2003).

To understand the epidemiology of malaria, it is essential to study the dynamics of the disease (Rubio-Palis, 1994). One of the basic approaches to measuring the risk of transmission of malaria in an endemic area is to estimate the transmission rates indirectly by the determination of vectorial capacity (VC) (Lee *et al*., 2001) of the vector(s). The vectorial capacity measures the potential for malaria transmission and may be expressed as the expected number of humans infected per infected human per day, assuming perfect transmission efficiency (Smith & McKenzie, 2004), the formula for which was developed by Garrett-Jones (1964). The estimation of VC requires accurate measurements of mosquito and human host population sizes, mosquito blood feeding habits and environmental conditions (Garrett-Jones, 1964, Reisen & Boreham, 1982; Martens *et al*., 1999).

The present study was conducted to use VC to evaluate the intensity and pattern of transmission in the malaria endemic area in Şanlıurfa province, Turkey and to discuss the malaria situation there.

Materials and methods

The study was conducted in four selected villages, Sandı (37° 19' N 39° 34' W), Pamuklu (37° 36' N 39° 19' W), Persiverek (37° 21' N 39° 34' W), and Birecik (37° 02' N 37° 59' W) in Şanlıurfa Province, south-eastern Turkey. The villages were selected due to their high malaria incidence, and their low socioeconomic conditions.

To estimate the human biting rate (ma), mosquitoes were collected from houses and animal sheds for a period of 4 months (from July to November in 2002). Anopheline mosquitoes were collected by 10 minute/human bait catches with the aid of torches and an aspirator between 7:30 am and 8.30 am in the same locations of the selected villages. In the collection period, the number of householders within houses was also counted in order to obtain the mosquito density related to humans (m), which can be estimated from the proportion of blood fed female mosquitoes collected per night per household (Garrett-Jones, 1964; Freier, 1989; Reisen, 1989; Gilles, 1993).

The human blood index (HBI), which is denoted by 'a', is estimated by the proportion of the human blood meals taken by a mosquito population which are obtained from humans (Martens *et al*., 1999) to the length of the gonotrophic cycle (Kiszewski *et al*., 2004).

A total of 416 blood fed female mosquitoes were collected and kept separately for the different villages. The blood fed females were smeared on to Whatman No.2 filter papers and were wrapped in waxed paper and stored. Then, to determine HBI, the source of the blood meal was determined by simple precipitin tests as described by Macdonald (1957); Washino & Tempelis (1983); Kay *et al*. (1979), amongst others. Due to its low cost, precipitin test is mostly preferred to ELISA (Wekesa *et al*, 1997).

In the selected villages, 277 *An. sacharovi* females were dissected to determine parity according to the appearance of the ovarian traqueal system (Detinova, 1962).

One hundred blood-fed females were selected randomly from the field collection, and the duration of the gonotrophic cycle was observed under laboratory conditions (Hacettepe University, Dept. of Biology, Ecological Sciences Research Laboratories, EBAL) at 27°C and a relative humidity of 70%.

The duration of the sporogonic cycle (n) for *P. vivax* in the *Anopheles* host was estimated by the method of Oganov-Rayevsky (Detinova, 1962). Temperature data needed for the estimation of the duration of sporogonic cycle were obtained from the Turkish State Meteorological Service.

The VC was calculated from the following formula:

$$VC = \frac{ma^2 p^n}{-\ln p}$$

where m= the relative density of *An. sacharovi*, a= the probability that the mosquito will take a human blood-meal during a particular day, n= the duration of the sporogonic cycle (in days) and p= the probability of the vector surviving one day, and was estimated from the formula :

$$p = \sqrt[cg]{parity}$$

where cg = the duration of gonotrophic cycle and parity is the proportion of parous females (Garrett-Jones, 1964; WHO, 1975; Dye, 1992; Gilles, 1993; Rubio-Palis, 1994). After the above calculations were performed, VC was estimated for each selected village.

Results

The blood-fed female collection results in the selected villages are shown in Table 1. As a result of the precipitin tests, there was no significant difference in the host preference of *An. sacharovi* among the four selected villages (χ^2= 2.649; P > 0.05). However, the human blood index was found as 19.5% (n = 416) from both

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Table 1. The percentages of mosquitoes feeding on humans and cattle/sheep in houses and animal sheds (figures in parentheses are actual numbers of mosquitoes).

Sites	**Human %**	**Cattle/Sheep %**	**Total**
Animal shed	15.8 (40)	84.2 (213)	253
House	25.2 (41)	74.8 (122)	163
Total	**19.5 (81)**	**80.5 (335)**	**416**

the house and animal shed catches whereas the animal blood index was found to be 74.8% (n = 163) from the house catches (Table 1). In addition, approximately six people slept in one room and the average human biting rate (ma) for the four selected villages was found to be 0.14, but the human biting rate for Birecik was found to be high since the population of Birecik is higher than the other villages.

As a result of the dissection of 277 *An. sacharovi* females, the rate of parous females was found to be between 85.24 - 92.98 % and the probability of daily survival rate was found as 0.85 on average.

The duration of the gonotrophic cycle (cg) is based on the mean interval between ovipositions. The frequency of feeding depends on how rapidly a blood meal is digested and how fast the temperature rises. Under laboratory conditions (at 27°C and a relative humidity of 70%), the mean (± SD) gonotrophic cycle was found to be 6.31 ± 1.50 days.

According to the method of Oganov-Rayevsky (Detinova, 1962; table 5), the values of the duration of the sporogonic cycle (n) of *Plasmodium vivax* in the study sites were found as 9.5 days for Sandı, Pamuklu and Persiverek and as 8.5 days for Birecik.

According to the calculations, VC was found to be 0.22 on average for the four selected villages (Table 2).

Discussion

All of the selected villages have low socio-economic conditions and a high rate of population movement, as farmers move to other villages for work (Alten *et al*., 2003). From July to November labourers were settled into temporary settlements close to agricultural areas, which were usually near to larval breeding sites. Moreover, local people spend their evenings outdoors and, depending on the weather condition, slept on the roof at night exposing themselves to mosquito bites (Kasap & Demirhan, 1995; Alten *et al*., 2003). In addition, there is a high *An. sacharovi* population density during the summer season owing to the suitable conditions for breeding, feeding and resting (Şimşek, 2006). Hence, under these conditions, human-vector contact is likely to be increased.

Previous studies point out that in regions with higher socio-economic conditions; human biting rates are higher within households than the

Table 2. The vectorial capacity values* of *Anopheles sacharovi* that were estimated for different villages. The values in parenthesis are sample size.

Study site	**ma**	**HBI (%)**	**a**	**Parity (%)**	**p**	**n**	**p^n**	**VC**
Sandi	0.230	21.3 (319)	0.0336	92.98 (114)	0.989	9.5	0.90	0.63
Birecik	0.215	17 (59)	0.0296	85.24 (61)	0.975	8.5	0.81	0.19
Pamuklu	0.0395	5 (18)	0.0079	89.18 (37)	0.982	9.5	0.84	0.014
Persiverek	0.071	10 (20)	0.0158	90.77 (65)	0.985	9.5	0.87	0.06
Mean							**0.85**	**0.22**

*ma = human biting rate, HBI = Human Blood Index, a = the probability that the mosquito will take a human blood-meal during a particular day, p^n =the proportion of vectors surviving the parasite's incubation period.

animal sheds (Garrett-Jones, 1964; Boreham & Garrett-Jones, 1973; Garrett-Jones, 1980; Yaghoobi-Ershadi *et al*., 2001). However, in the present study, mosquitoes from house catches have a high animal-biting rate (74.8%). The main reason for this result may be due to the houses and animal sheds being located very close to each other and the people living together due to poor socio-economic conditions. In the summer, when the sheds are very hot and open, these places are not suitable locations for *An. sacharovi* resting after blood feeding. Consequently, blood-fed mosquitoes move to houses to complete their gonotrophic cycle (Alptekin & Kasap, 1996). Feeding preference is strongly influenced by the availability of particular hosts, and certain innate and species-specific properties of the vector affect choice. Thus, these behavioural characteristics range from complete zoophily to complete anthropophily with a continuum of intervening gradient (Kiszewski *et al*., 2004).

The high parous rates imply that the probability of daily survival of the vectors for efficient transmission of infection is high (Ree & Hwang, 2000). High parity values may be evidence for high egg development and high blood intake. The duration of the gonotrophic cycle of *An. sacharovi* was found as 6.3 days at 27°C, however, in previous studies, it was observed as 13.2 days at 24°C and 9.2 days at 28°C (Kasap *et al*., 1989). With increasing temperatures, the gonotrophic cycle becomes shorter, suggesting that the blood-feeding frequency of mosquitoes, thus VC, increases. The average daily survival rate, which is related with endemicity, was found to be 0.85. The result supports a previous study where the mean survival value was 0.858 for *An. sacharovi* (Kiszewski *et al*., 2004).

Consequently, the average VC for the selected villages of Şanlıurfa province was found to be 0.22. The low VC values could indicate that the malaria transmission is very low due to the low human blood index. However, there is an increasing trend in temperature in south-eastern Anatolia (Türkes *et al*., 2002). Thus, it is possible that increasing temperature could lead to an increase in the VC in future. More advanced studies on the estimation of VC could lead to epidemiological surveillance of immigration from endemic malaria areas in relation to the changes in the environmental conditions and also could determine the density and distribution of mosquito populations in this region.

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