Bionomics of anopheles vectors in
Zabid District, Al-Hodeidah
Governorate, Republic of Yemen

M.T. Al-Maktari and H.K. Bassiouny

ABSTRACT The bionomics of anopheles vectors were analysed in randomly selected centres, represent-
ating fixed and spot-check stations. Three anopheles species were found. Anopheles arabiensis was
the most prevalent species (84.2%) with a sporozite rate of 0.7%, followed by A. culicifacies adenensis
(14.9%) and A. rhodesiensis ripiculis (0.9%). Maximum indoor resting density was recorded during
March, July and August. Positive sprayed sites for females were higher in bedrooms (40.4%) than
animal sheds (26.9%). A total of 2560 anopheles larvae were collected of which 79.5% were A. arabi-
ensis, 19.4% were A. culicifacies adenensis and 1.1% A. rhodesiensis ripiculis. A. arabiensis was as-
sumed to be the most efficient malaria vector based on epidemiological evidence and the finding of
natural sporozoite infected females.

La Revue de Santé de la Méditerranée orientale, Vol. 5, No. 4, 1999

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Bionomie des anophèles vecteurs dans le district de Zabid, Gouvernorat de Al-Hodeidah
(République du Yémen)

RESUME La bionomie des anophèles vecteurs a fait l'objet d'une analyse dans des centres choisis au
hasard représentant des postes fixes et de contrôle intermittents. On a trouvé trois espèces anophél-
liennes. A. arabiensis était l'espèce la plus répandue (84,2%) avec un indice sporozoïtique de 0,7% sui-
vie par A. culicifacies adenensis (14,9%) et A. rhodesiensis ripiculis (0,9%). La densité maximale
dans les refuges de repos à l'intérieur des habitations a été enregistrée durant les mois de mars, juillet
et août. Le nombre de sites pulvérisés qui étaient positifs pour les anophèles femelles était plus élevé
dans les chambres (40,4%) que dans les abris d'animaux (26,9%). Au total, 2560 larves d'anophèles
ont été recueillies, dont 79,5% étaient A. arabiensis, 19,4% étaient A. culicifacies adenensis et 1,1%
A. rhodesiensis ripiculis. A. arabiensis a été présumé comme étant le vecteur du paludisme le plus
efficace d'après les données épidémio-logiques et le constat de la présence d'anophèles infectants.

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Received: 06/04/98; accepted: 01/07/99
Introduction

Malaria is considered the greatest challenge of all health problems in tropical countries. The *Plasmodium* parasite undergoes a complete cycle of sporogony leading to the formation of the infective stages, which propagate the infection during the feeding process of the mosquito. The efficiency of transmission of the disease depends mainly on the presence of favourable environmental conditions for the occurrence of suitable anopheline vectors [7].

Malaria has continued to be a major public health problem in the Republic of Yemen. In 1993, 37,451 malaria cases were confirmed and the slide positivity rate was 22.9% compared with 14% and 4.6% in 1991 and 1985 respectively [2]. The Tihama plain is considered the most malarious area in the country (Delfini LF, unpublished report, 1986). The steady expansion of agriculture projects in this area has contributed to the increase in breeding of vectors of malaria. Moreover there are five main wadis (Maor, Surudud, Siham, Zabid and Rima) passing through Tihama plain that are also natural breeding places.

The present work aimed to contribute to our knowledge of malaria control by investigating the bionomics of anopheline vectors prevailing in the Zabid district. This area is one of the most endemic malarious areas in Tihama plain under natural field conditions. The ultimate goal is to help in the formulation of a comprehensive malaria control programme in the Republic of Yemen.

Materials and methods

Design

Longitudinal entomological surveys were conducted in the Zabid district of the Al-

Hodeidah Governorate for 6 months from March to August 1994.

Adult mosquito survey

By using a stratified random sampling method, five centres were selected to represent fixed catching stations: Zabid, Al-Qurashiyah Ulya, Al-Maislah, Al-Tuhaytah, and Assalamah. In these centres, 20% of the houses and 10% of the animal sheds were randomly chosen and surveyed monthly for adult mosquitoes. Four additional centres were selected to represent spot-check stations: Al-Musawi-fah, Al-Mahatt, MahallMubarak and Al-Majahsah. In these centres, 10% of the houses and 5% of the animal sheds were randomly chosen monthly for testing in order to supplement and confirm the results of the regularly surveyed localities. Mosquitoes were collected by the spray sheet collection technique in the morning between 06.00 and 10.00 [3]. They were collected and identified according to the key of Mattingly and Knight [4]. In addition, the salivary glands of the captured female mosquitoes were dissected for the detection of sporozoites [3].

Larvae survey

Permanent water sources of the surveyed centres were identified and mapped. The sources of water were irrigation canals, riverbeds, pools of the mosques and water collection near the pumps that are scattered along the villages. Also, sources inside houses were investigated and recorded, such as storage tanks, artificial containers and basins. The larval survey was done monthly using dipping and netting techniques [3] according to the type and size of the breeding places investigated. Larvae were identified according to the key of Mattingly and Knight [4].
Statistics
Data was analysed using Epi-Info and SPSS. A P-value < 0.05 was considered statistically significant. Arithmetic mean and standard deviation were used as summary statistics. The one-sample Kolmogorov–Smirnov Z-test was used to examine the months variation, while the Z-test was used for comparison of two proportions and replaced with Fisher exact test when mandated by sparse data. The chi-squared test for comparison between more than two proportions was used and the Kruskal–Wallis one-way analysis of variance was used for comparison between more than two independent groups.

Results
Table 1 shows that the overall percentage of positive sprayed sites for female mosquitoes was 39.7%. It was higher in bedrooms (40.4%) than in animal sheds (26.9%), although no significant correlation could be detected. The percentage positive in bedrooms and animal sheds was significantly higher in fixed than spot-check catching stations ($\chi^2 = 9.72, P < 0.01$).

Table 2 demonstrates that *A. arabiensis* was the most prevalent species constituting 84.2% of the total collected females (713), followed by *A. culicifacies adenensis* (14.9%). The least prevalent species was *A. rhodesiensis rupicolus* (0.9%). A significant correlation was recorded between percentage of positive sprayed sites and the month of collection ($\chi^2 = 70.23, P < 0.01$). Moreover, a higher indoor resting density (IRD) was recorded during March, July and August for the total of collected females and for each species as indicated by the Kolmogorov–Smirnov Z-test. Dissection of the salivary glands revealed that the sporozoite rate was 0.7% among collected *A. arabiensis* only.

Table 3 shows that out of 845 different breeding sites investigated, 42.8% were found positive for anophele larvae. Over the study months, the percentage of positive sites was significantly higher in August and March ($\chi^2 = 68.43, P < 0.01$).

Table 4 shows that out of 2560 collected larvae, *A. arabiensis* was the most abundant species (79.5%), followed by *A. culicifacies adenensis* (19.4%); the least abundant was *A. rhodesiensis rupicolus* (1.1%). Over the study months, maximum mean number of larvae collected and larval density were recorded mainly in March, July and August (Kruskal–Wallis $\chi^2 = 15.25, P < 0.01$). However, no significant difference could be detected in larval density between the months except for *A. rhodesiensis rupicolus* (Kolmogorov–Smirnov $Z = 1.633, P < 0.01$).

Discussion
In 1993, a survey conducted in the Republic of Yemen revealed that 14 anopheline species were identified, of which *A. arabiensis* and *A. culicifacies adenensis* are still considered to be the most common vector species [6]. This finding corresponds with the results of our study where *A. arabiensis* was the most prevalent species, constituting 84.4% of the total collected adult mosquitoes. This observation is similar to the findings of Muttingly and Knight [4] and Kouznetsof [7] who reported that *A. arabiensis* was widely distributed in Tihama. Omer added that it was abundant throughout the year, even during the hot dry season [8]. Zahar emphasized the importance of *A. arabiensis* as a vector for malaria transmission in the Republic of Yemen as well as to
the nearby countries of Ethiopia, Saudi Arabia, Somalia and Sudan [9].

According to the findings of our study, a large number of captured females of *A. arabiensis* were from bedrooms rather than animal sheds, which indicates their higher anthropophagic tendency. Furthermore, the finding of natural sporozoites in the salivary glands emphasizes their epidemiological importance in the dynamics of mosquito-borne pathogens responsible for the continued transmission of malaria in the study area. Bassiouny and Al-Maktari reported the hypendemicity of malaria in the Zabid district based on both parasite and spleen surveys where *P. falciparum* was the most predominant species representing 91.6% (Bassiouny HK, Al-Maktari MT, unpublished data, 1995).

*A. culicifacies adenensis* was the second most abundant species constituting 14.5%. This finding was confirmed by Kouzentsov [7] and Ahamed [10]. *A. culicifacies adenensis* is still the main vector of malaria transmission in Pakistan and India [11]. *A. rhodesiensis rupicolus* was the least prevailing species (0.9%). This result was also reported by Kouznetsov [7] and Ahamed [10], who recorded a low prevalence of this species in the Tihama region. Its low density was explained by Kouznetsov who noted that after the autumn rains over the Tihama mountains, occasional pools formed that contained anopheeline larvae [7]. The pools were, as a rule, rather short-lived, their duration often not sufficient for the completion of the egg-to-adult cycle. Still, *A. rhodesiensis rupicolus* is
Table 2 Distribution of collected female anophelines according to their species, indoor resting density (IRD) and sporozoite rate

<table>
<thead>
<tr>
<th>Data of study</th>
<th>Duration of study</th>
<th>Total Sporozoite rate K–SZ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>March</td>
<td>April</td>
</tr>
<tr>
<td>No. of sprayed sites (bedrooms + animal sheds)</td>
<td>No.</td>
<td></td>
</tr>
<tr>
<td>Positive sprayed sites for female anopheline</td>
<td>No.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Total number of female anophelinesIRD</td>
<td>No.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anopheline species</th>
<th>No.</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A. arabiensis</td>
<td>113</td>
<td>61</td>
<td>20</td>
<td>87</td>
<td>123</td>
<td>198</td>
<td>600</td>
<td>4</td>
</tr>
<tr>
<td>IRD</td>
<td>2.5</td>
<td>2.4</td>
<td>2.2</td>
<td>3.0</td>
<td>3.1</td>
<td>3.2</td>
<td>64.4</td>
<td></td>
</tr>
<tr>
<td>A. culicifacies adenensis</td>
<td>17</td>
<td>10</td>
<td>7</td>
<td>9</td>
<td>18</td>
<td>45</td>
<td>106</td>
<td>0</td>
</tr>
<tr>
<td>IRD</td>
<td>0.4</td>
<td>0.4</td>
<td>0.8</td>
<td>0.3</td>
<td>0.5</td>
<td>0.7</td>
<td>14.9</td>
<td>0</td>
</tr>
<tr>
<td>A. rhodoonioea</td>
<td>No.</td>
<td>2</td>
<td></td>
<td>2</td>
<td>3</td>
<td>7</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>rupicolas</td>
<td>IRD</td>
<td>0.05</td>
<td></td>
<td></td>
<td>0.05</td>
<td>0.04</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

\*χ² = 70.23, P < 0.01
P² < 0.05
*Sporozoite rate of A. arabiensis
K–SZ = Kolmogorov–Smirnov Z-test for the uniform distribution

considered to be one of the non-vector species as reported by the Malaria Control Programme [2].

Our study showed that the three available female anopheline vectors had two peaks of abundance, in March and in August. This finding agrees with those reported by the agrometeorological data summary [12] and Pleisjer [13]. They reported a seasonal activity for the three species that reached a maximum number in the cooler time of the year, such as August which is the rainiest month in the country. The relatively low anopheline numbers during the hottest months between the peaks could be due to a reduction in vector activity, as well as to a general reduction in breeding sources since most of the wadis dry up.

We found that 42.8% of the different breeding sites investigated were positive for anopheline larvae. A. arabiensis were collected from all breeding sites, while A. culicifacies adenensis larvae were collected mostly from pools of mosques, basins, storage tanks and artificial containers. A. rhodesiensis rupicolas larvae were collected from the irrigation canals, riverbeds and water near pumps. Similar results were reported by Kouznetsov [7]. The larvae of the two most common vector species, A. arabiensis and A. culicifacies adenensis, were found in all pools of mosques in the Zabid district. These pools are open basins of water near the mosques and are used mainly for ritual ablutions and for washing.
Table 3 Distribution of breeding places according to catching stations by month

<table>
<thead>
<tr>
<th>Month</th>
<th>Fixed stations</th>
<th>Spot-check stations</th>
<th>Total</th>
<th>Z-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. examined</td>
<td>Positive No.</td>
<td>%</td>
<td>No. examined</td>
</tr>
<tr>
<td>March</td>
<td>112</td>
<td>64</td>
<td>57.1</td>
<td>17</td>
</tr>
<tr>
<td>April</td>
<td>120</td>
<td>54</td>
<td>54.0</td>
<td>26</td>
</tr>
<tr>
<td>May</td>
<td>122</td>
<td>37</td>
<td>30.3</td>
<td>15</td>
</tr>
<tr>
<td>June</td>
<td>140</td>
<td>41</td>
<td>29.3</td>
<td>20</td>
</tr>
<tr>
<td>July</td>
<td>112</td>
<td>42</td>
<td>37.5</td>
<td>30</td>
</tr>
<tr>
<td>August</td>
<td>107</td>
<td>72</td>
<td>67.3</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>713</td>
<td>310</td>
<td>43.5</td>
<td>132</td>
</tr>
</tbody>
</table>

*Fisher exact probability (2-tailed)

Table 4 Distribution of anopheline larvae according to species and larval density by month

<table>
<thead>
<tr>
<th>Month</th>
<th>No. of dips</th>
<th>Larvae collected</th>
<th>Identified anopheline larvae</th>
<th>A. arabiensis</th>
<th>A. culicifacies adenosis</th>
<th>A. rhodesiennis ripiculcus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
<td>No./dip</td>
<td>No.</td>
<td>No./dip</td>
<td>No.</td>
</tr>
<tr>
<td>March</td>
<td>586</td>
<td>476</td>
<td>0.81</td>
<td>372</td>
<td>0.63</td>
<td>96</td>
</tr>
<tr>
<td>April</td>
<td>341</td>
<td>205</td>
<td>0.60</td>
<td>156</td>
<td>0.46</td>
<td>49</td>
</tr>
<tr>
<td>May</td>
<td>293</td>
<td>111</td>
<td>0.38</td>
<td>93</td>
<td>0.32</td>
<td>18</td>
</tr>
<tr>
<td>June</td>
<td>548</td>
<td>315</td>
<td>0.57</td>
<td>238</td>
<td>0.43</td>
<td>77</td>
</tr>
<tr>
<td>July</td>
<td>482</td>
<td>423</td>
<td>0.88</td>
<td>351</td>
<td>0.73</td>
<td>72</td>
</tr>
<tr>
<td>August</td>
<td>860</td>
<td>1030</td>
<td>1.20</td>
<td>824</td>
<td>0.96</td>
<td>185</td>
</tr>
<tr>
<td>Total</td>
<td>3110</td>
<td>2560</td>
<td>0.82</td>
<td>2034</td>
<td>0.85</td>
<td>497</td>
</tr>
</tbody>
</table>

79.5% 19.4% 1.1%

K-SZ 0.57 0.69 0.82 1.63

X ± s 3.33 ± 0.43 2.78 ± 0.40 0.52 ± 0.19 2.33 ± 2.59

X² 15.25

P > 0.05  P < 0.01  K-SZ = Kolmogorov-Smirnov Z-test for the uniform distribution

Merucci noted that these pools were the principal breeding sites for mosquitoes, especially A. arabiensis [14].

Regarding the abundance of the collected larvae in the studied area, the results revealed that A. arabiensis larvae were the most abundant species (79.5%), A. culicifacies adenosis larvae were the second most common species (19.4%) and A. rhodesiensis ripiculcus larvae constituted 1.1%.
These findings agree with the previous report of Ahamed [10]. The larvae collected in our study had two peaks of abundance and a larval density irrespective of the species of the anopheline vectors mainly in March and August. These two peaks of abundance coincided with the recorded peaks of abundance of the adult mosquitoes. It seems that the temperature during peaks is optimal for rapid and synchronous development and high survival from eclosion through emergence.

Conclusions

The large number of captured females of *A. arabiensis* from bedrooms indicates their anthropophagic behaviour. That, in addition to the presence of sporozoites in their salivary glands, are of epidemiological importance in the dynamics of mosquito-borne pathogens responsible for the continued transmission of malaria in the Zabid district. Further investigation is needed in the Republic of Yemen to study the mosquito-host feeding preferences and to assess the epidemiological effectiveness of the malaria vector, as it is the blood meal identification of a vector that leads to its incrimination. Finally, it is vitally important to increase community participation in environmental concerns. People should be encouraged to drain or fill in any unnecessary water collection systems since this could be an effective component of a vector control programme.

References


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**Vector control**

Expertise and advice were provided for monitoring and surveillance and analytical work in relation to insecticide susceptibility or resistance. In this connection, the Regional Office continued to support countries in scientific and research aspects of insecticide resistance. The use of impregnated bednets was further enhanced, and consultant services and training were provided to a number of countries. In this regard, vector control in relation to malaria received a high priority and major support in particular in Islamic Republic of Iran, Pakistan, Djibouti, Sudan and Republic of Yemen.