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

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الخصائص البيئية لبعوض الأنوفيل في منطقة زبيد بمحافظة الحديدة بالجمهورية اليمنية

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خلاصة: تم تحليل الخصائص البيئية لبعوض الأنوفيل الناقل للملاريا، وذلك في مراكز مختارة عشوائياً، تمثل المحطات الثابتة ومحطات الفحص العشوائي. فوجدت ثلاثة أنواع من الأنافيل. وكانت الأنوفيلة العربية هي النوع الأكثر انتشاراً (84.2%) حيث كان معدل وجود حيواناتها البوغية 0.7%. وجاءت بعد ذلك الأنوفيلة البعوضية المظهر (14.9%)، والأنوفيلة الروديسية (0.9%). وسجلت أقصى كثافة لاستراحة البعوض داخل المنازل في شهور آذار/مارس وتموز/يوليو وآب/أغسطس. وكانت الأماكن المرشوشة بالمبيدات والإيجابية لإناث البعوض أكثر وجوداً في غرف النوم (40.4%) عنها في حظائر الحيوانات (26.9%). ولقد تم جمع أعداد مجموعها 2560 من يرقات الأنافيل، كان 79.5% منها من الأنوفيلة العربية، بينما كان 19.4% من الأنوفيلة البعوضية المظهر، و1.1% من الأنوفيلة الروديسية. ولقد اعتبرت الأنوفيلة العربية أنشط نواقل الملاريا على أساس البينات الوبائية، والعثور على إناث مصابة بالعدوى الطبيعية بالحيوانات البوغية.

ABSTRACT The bionomics of anopheline vectors were analysed in randomly selected centres, representing fixed and spot-check stations. Three anopheline species were found. *Anopheles arabiensis* was the most prevalent species (84.2%) with a sporozoite rate of 0.7%, followed by *A. culicifacies adenensis* (14.9%) and *A. rhodesiensis rupicolus* (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 anopheline larvae were collected of which 79.5% were *A. arabiensis*, 19.4% were *A. culicifacies adenensis* and 1.1% *A. rhodesiensis rupicolus*. *A. arabiensis* was assumed to be the most efficient malaria vector based on epidemiological evidence and the finding of natural sporozoite infected females.

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 intermittent. On a trouvé trois espèces anophéliennes. *A. arabiensis* était l'espèce la plus répandue (84,2%) avec un indice sporozoïtique de 0,7% suivie par *A. culicifacies adenensis* (14,9%) et *A. rhodesiensis rupicolus* (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 rupicolus*. *A. arabiensis* a été présumé comme étant le vecteur du paludisme le plus efficace d'après les données épidémiologiques et le constat de la présence d'anophèles infectants.

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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 [*1*].

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, Surdud, 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 Asslamah. In these centres, 20% of the houses and 10% of the animal sheds were randomly chosen and surveyed monthly for adult mosquitos. Four additional centres were selected to represent spot-check stations: Al-Musawfah, 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. Mosquitos 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 mosquitos 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 [*5*] 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 mosquitos 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 anopheline 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 larvae 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 mosquitos. This observation is similar to the findings of Mattingly and Knight [4] and Kouznetsov [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

Table 1 **Distribution of the sprayed sites for adult female anopheline mosquitos according to the surveyed centres**

Surveyed centres	Sprayed sites for female anopheline mosquitos									FEP test (2-tailed)
	Bedrooms			Animal sheds			Total			
	No. sprayed	Positive No.	%	No. sprayed	Positive No.	%	No. sprayed	Positive No.	%	
Fixed stations										
Zabid	120	51	42.5	4	1	25.0	124	52	41.9	0.639
Al-Tuhaytah	108	39	36.1	2	0	0.0	110	39	35.5	0.538
Al-Maislah	80	41	51.3	2	1	50.0	82	42	51.2	1.000
Al-Qurashiya Ulya	30	19	63.3	6	2	33.3	36	21	58.3	0.210
Asslamah	24	11	45.8	4	1	25.0	28	12	42.9	0.613
Subtotal	362	161	44.5	18	5	27.8	380	166	43.7	0.455
Spot-check stations										
Al-Majahsah	60	15	25.0	2	1	50.0	62	16	25.8	1.000
Al-Mahatt	30	11	36.7	1	0	0.0	31	11	35.5	1.000
Al-Musawfah	12	3	25.0	3	0	0.0	15	3	20.0	0.529
Mahall-Mubarak	24	7	29.2	2	1	50.0	26	8	30.8	1.000
Subtotal	126	36	28.6	8	2	25.0	134	38	28.4	0.218
Grand total	488	197	40.4	26	7	26.9	514	204	39.7	1.36[a]

[a] *Z test*
FEP = Fisher exact probability

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 hypoendemicity 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 anopheline 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**

Data of study		Duration of study						Total	Sporozoite rate		K–SZ
		March	April	May	June	July	August		No.	%	
No. of sprayed sites (bedrooms + animal sheds)	No.	90	84	83	83	88	86	514			
Positive sprayed sites for female anopheline [a]	No.	40	25	9	29	40	61	204			
	%	44.4	29.8	10.8	34.9	45.5	70.9	39.6			
Total number of female anopheline	No.	132	71	27	96	143	244	713			
	IRD	3.3	2.6	3.0	3.3	3.6	4.0	100.0			0.612[b]
Anopheline species											
A. arabiensis	No.	113	61	20	87	123	196	600	4	0.7[c]	0.735[b]
	IRD	2.8	2.4	2.2	3.0	3.1	3.2	84.4			
A. culicifacies adenensis	No.	17	10	7	9	18	45	106	0	0.0	0.735[b]
	IRD	0.4	0.4	0.8	0.3	0.5	0.7	14.9			
A. rhodesiensis rupicolus	No.	2	–	–	–	2	3	7	0	0.0	1.225[b]
	IRD	0.05	–	–	–	0.05	0.04	0.9			

[a] $\chi^2_5 = 70.23$, $P < 0.01$
[b] $P < 0.05$
[c] *Sporozoite rate of* A. arabiensis
K–SZ = Kolmogorov–Smimov 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 Pleijsier [*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 rupicolus* 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**

Month	Breeding places investigated									Z-test
	Fixed stations			Spot-check stations			Total			
	No. examined	Positive No.	%	No. examined	Positive No.	%	No. examined	Positive No.	%	
March	112	64	57.1	17	10	58.8	129	74	57.4	0.490
April	120	54	54.0	26	8	30.8	146	62	42.5	1.330
May	122	37	30.3	15	1	6.7	137	38	27.7	0.067[a]
June	140	41	29.3	20	4	20.0	160	45	28.1	0.866
July	112	42	37.5	30	14	46.7	142	56	39.4	0.911
August	107	72	67.3	24	15	62.5	131	87	66.4	0.447
Total	713	310	43.5	132	52	39.4	845	362	42.8	0.87

[a]*Fisher exact probability (2-tailed)*

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

Month	No. of dips	Larvae collected		Identified anopheline larvae					
				A. arabiensis		*A. culicifacies adenosis*		*A. rhodesiensis rupicolus*	
		No.	No./dip	No.	No./dip	No.	No./dip	No.	No./dip
March	586	476	0.81	372	0.63	96	0.16	8	0.01
April	341	205	0.60	156	0.46	49	0.14	0	0.00
May	293	111	0.38	93	0.32	18	0.06	0	0.00
June	548	315	0.57	238	0.43	77	0.14	0	0.00
July	482	423	0.88	351	0.73	72	0.15	0	0.00
August	860	1030	1.20	824	0.96	185	0.22	21	0.02
Total	3110	2560	0.82	2034	0.65	497	0.16	29	0.02
				79.5%		19.4%		1.1%	
K–SZ			0.57		0.69		0.82		1.63[a]
$\bar{X} \pm s$		3.33 ± 0.43		2.78 ± 0.40		0.52 ± 0.19		2.33 ± 2.59	
χ^2_2				15.25[b]					

[a]*P > 0.05* [b]*P < 0.01* *K–SZ = Kolmogorov–Smirnov Z-test for the uniform distribution*

Merucci noted that these pools were the principal breeding sites for mosquitos, 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 adenensis* larvae were the second most common species (19.4%) and *A. rhodesiensis rupicolus* 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 mosquitos. 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

1. Radford AJ, Van Leeuwen H, Christian SH. Social aspects in the changing epidemiology of malaria in the highlands of New Guinea. *Annals of tropical medicine and parasitology*, 1976, 70:11–23.
2. *Malaria Control Programme. Annual descriptive report of year 1993.* Sana'a, Republic of Yemen, Ministry of Public Health, 1993.
3. *Manual on practical entomology in malaria prepared by the WHO division of malaria and other parasitic diseases.* Geneva, World Health Organization, 1975.
4. Mattingly PF, Knight KL. The mosquitos of Arabia-1. *Bulletin of the British Museum* (Natural History) entomology, 1956, 4 (3):104–10.
5. *Entomological field techniques for malaria control part I. Learner's guide.* Geneva, World Health Organization, 1992.
6. *Malaria Control Programme. Report survey.* Sana'a, Republic of Yemen, Ministry of Public Health, 1993.
7. Kouznetsov RL. *Distribution of anophelines in Yemen Arab Republic and its relation to malaria.* Geneva, World Health Organization, 1976.
8. Omer SM. Survival of female *Anopheles gambiae* Giles through a 9-month dry season in Sudan. *Bulletin of the World Health Organization*, 1970, 42(2):319–30.
9. Zahar AR. Review of the ecology of malaria vectors in the WHO Eastern Mediterranean Region. *Bulletin of the World Health Organization*, 1974, 50(5):427–40.

10. Ahamed NU. *Distribution of* Anopheles meigen *(Dipteria: culicidae) and a short description of the Tihama Region.* Al-Hodeidah, Yemen Arab Republic, Malaria Control Programme, 1979.

11. Krishnaswami AK. *Vectors of malaria in India.* 1st ed. Delhi. National Society for Malaria and Other Mosquito-borne Diseases, 1957.

12. *Agro-meteorological data summary.* Al-Hodeidah, Yemen Arab Republic Ministry of Agriculture, United Nations Development Programme/Food and Agriculture Organization, 1975.

13. Pleijsier LK. *Aspect of soil and soil salinity in the Tihama region, Yemen Arab Republic.* Rome, United Nations Development Programme/Food and Agriculture Organization, 1978.

14. Merucci L. Aleune specie di anofeli riscontrate in varie loacalita dello Yemen (Arabia Sud-occidentale). [Some species of anopheles found in some localities of Yemen (south-west Saudi Arabia).] *Nuovi annali d'igiene e microbiologica,* 1954, 5:440–4.

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, Somalia, Sudan and Republic of Yemen.

Source: The work of WHO in the Eastern Mediterranean Region. Annual Report of the Regional Director. 1 January–31 December 1998. *Pages 98–9.*