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MOSQUITO BREEDING HABITATS IN TIHAMA LOWLANDS OF ASIR REGION, KINGDOM OF SAUDI ARABIA

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ABSTRACT

Water collections which may provide breeding habitats for mosquitoes in Tihama lowland, Asir region, Kingdom of Saudi Arabia, were surveyed throughout the period from September 2000 to August 2002. A total of 2379 from 11409 surveyed breeding sites (20-85 %) were positive for mosquitoes. Mosquito larvae were found in a variety of water collections including temporary, permanent, natural or man-made habitats. The abundance of different mosquito species and the seasonal productivity of mosquitoes in each type of these habitats were determined. Permanent and semi-permanent water were the main sites for mosquito breeding. Twenty mosquito species were identified in the study area; Seven anopheline species (*Anopheles d'thali, An. rupicolus, An. arabiensis, An. sergentii, An. Multicolor, An. turkhudi* and *An. pretoriensis*); eight culicine species *(Culex pipiens* complex, *Cx. sinaiticus, Cx. tritaeniorhynchus, Cx. bitaeniorhynchus, Cx. sitiens, Cx. duttoni* and *Cx. tigripes*), four aedine species *(Ae. vexans arabiensis, Ae. vittatus, Ae. aegypti* and *Ae. caballus*) and *Culesita* spp. *An. d'thali, An. sergenti, An. arabiensis, Cx. sinaiticus, Cx. tritaeniorhynchus* were the most abundant anopheline and culicine species in most surveyed habitats. No significant difference was found between the prevalence of certain mosquito species and a specific chemical parameter of the breeding water in natural habitats. The number of mosquito aquatic habitats was highly variable either among seasons or between consecutive months. The year-round presence of immature mosquitoes indicates that the climatic conditions of the area are not limiting to the development of most prevailing mosquito species.

The regression coefficient between habitats availability, number of pools positive for mosquitoes and the seasonal abundance of mosquitoes were investigated.

INTRODUCTION

Tihama describes the whole of the coastal plain in the Arabian peninsula in the west and southwest of Saudi Arabia and Yemen. It consists of low hillocks bordering the north-south mountain chain. Wadis or river valleys occur in the Tihama and constitute the alluvial floodplains of the rivers as they emerge from the mountains (Abdoon and Alshahrani, 2003). The area has been a subject for various agricultural, developmental, resettlement and tourist projects. Rainfall and the changes in the Wadi systems, which have been made to ensure more effective use of the available water, result in many large and small water pools suitable for the breeding of certain mosquito species that are believed to be of the greatest importance in transmitting malaria and Rift Valley Fever (RVF).

In Addition to malaria which is endemic in Tihama (Abdoon and Alshahrani, 2003), an outbreak of RVF was reported in September, 2000 causing many causalities among humans and associated livestock along the southwestern border of Saudi Arabia. This was the first recorded outbreak of RVF outside of Africa (Jup *et al.*, 2000). RVF virus was isolated from *Aedes vexans arabiensis* and *Culex tritaeniorhynchus* in Al Ardah district in Jazan, where most human cases were reported (Jup *et al.*, 2000). The virus was also isolated from *Aedes vexans arabiensis* near the city of Muhayil in Asir region (Miller *et al.*, 2002).

Besides geographic location, knowledge of ecological features of mosquito breeding sites is a potential key element for implementing efficient and effective larvae control measures. Such measures have been shown to be an important tool to reduce disease transmission (Killeen *et al.*, 2002 and Sattler

et al., 2005). In spite of the work done by Abdullah and Merdan (1995) on the distribution and ecology of mosquito fauna in southwestern Saudi Arabia, yet no reliable scientific work has been published to clarify the characteristics of mosquito breeding habitats and their relative values in mosquito breeding. Following the 2000 epidemic of RVF, the present study was conducted to survey the potential breeding sources of mosquitoes in the area to assist in the planning and implemmenting of mosquito control programs in Asir region.

MATERIALS AND METHODS

The study area:

Asir region lies in the southwestern part of the Kingdom of Saudi Arabia between latitude 17°:27' - 21°:00' N and longitude 41°:23'- 44°:33' E. The Tihama lowlands of Asir region extend north south along the foothills of the Hijaz-Asir mountain ranges and coastal plains along the Red Sea. The area is divided into 2 major sub-regions: Tihamat Asir and Tihamat Qahtan.. Many mountains are scattered within these plains, particularly at the foothills of Sarawat mountains. The altitude along the coastal plains ranges between sea level up to 200 meter, whereas at the foothills in the east its range well between 300 and 800 meter above sea level. Many rocky valleys (Wadis) at the Tihama foothills or crossing these plains have permanent or seasonally running water, largely fed by heavy rains or floods from the Sarawat Mountains series. In general Livestock, including goats (the predominant animal), sheep, camels, and cattle, are present almost at all sites and are housed at night very close to the owners' homes. The eastern part of Tihama plains, along the mountains is characterized by semi-arid semi-humid mountain climate, whereas the western part, along the Red Sea, are well within the humid hot belt of the coastal desert. But generally, these lowlands are characterized by a high relative humidity which might reach up to 90 % in winter season at the coast and high

temperature (the average, maximum and minimum temperature recorded were 30.3, 39.4 and 20 °C, respectively). The average annual rainfall is of about 98 ml. Fairly lush growth of *Acacia* spp. in the plains and on the bottom of hill sides is seen. In Wadis vegetation is dense consisting of *Acacia* trees, *Ziziphus spina-christe* and Dom trees. The soils are sands, loamy silts and clays, of very low salt content, with little humus or nitrogen. Towards the sea is a belt of land with a high salt content.

Breeding site identification and mosquito sampling:

Water collections in 7 selected localities (Fig. 1) of Tihama lowlands (Al-Magarda, Mohayel, Al-Farsha, Rijal Alma'a, Al-Birk, Al-Qahma and Maraba) were occasionally surveyed for mosquito breeding habitats during the period of study. To record habitat type, every site was categorized and classified as shown in table (1). All visual classifications were done by the authors to maintain consistency. In addition, the general setting was qualitatively described, mentioning special features and general impressions. For monitoring the number of mosquito positive pools (where immatures were detected) and the monthly abundance of immature mosquitoes, a total of 1590 breeding sites identified in a preliminary phase of the study, were surveyed along the edges or banks of the Wadis in Mohayel and Al-Magarda from late September 2000 to August. 2002. More than 70% of these sites were weekly surveyed, while the rest were visited occasionally, employing 4 collection teams. Immature mosquitoes were sampled using a standard mosquito dipper (350 ml) and according to the methods described by the WHO (1975). In shallow and small habitats white plastic dippers (5 cm depth) and plastic pipettes were used. The number of samples collected was proportional to the surface of each water body (from 10 to 150 dips). During rainy seasons, the samples were taken within five days after each rainfall. Collected larvae were transferred to the laboratory ,preserved in 70% alcohol, and identified according to Hopkins *et al.* (1952);

Mattingly & Knight (1956); Harbach (1985&1988). Water samples from active breeding places were collected and transferred to the central Laboratory, Ministry of water, Asir Directorate for complete chemical analysis. The analysis includes the following parameters: pH value, Total alkalinity, Total hardness, Total dissolved solids, Ammonia, Nitrite, Nitrate, Chloride, Sulphate, Calcium, Magnesium and Iron. All meteorological records of the area were kindly provided by the meteorology and environmental protection administration in Saudi Arabia.

Statistical analysis

Data were statistically analyzed by using the SPSS computer program V. 10.0 (SPSS Inc., Chicago, USA).

RESULTS AND DISCUSSION

Collections of water, which provide breeding habitats for mosquito larvae, may be temporary or permanent, natural or man-made (Service, 1993). The determination of breeding habitats is of great benefit to mosquito control methods (Simsek, 2004). A total of 2379 from 11409 surveyed breeding sites (20.85 %) were positive for mosquitoes. The number of mosquito specimens collected was rather low over the period of study. This may be due to the regular and extensive use of larvicides in the region. In addition, occasional use of space and residual sprays assists in reducing the density of mosquitoes in the area. Mosquito larvae were found in a variety of water collections (table 1) including pools at the edges of Wadis; animal hoof pads; rock pockets; man made small ditches; temporal rain pool collections; cement basins and plastic barrels for animal drink; household water tanks; agriculture water catchments; Cesspits; discarded tires and tins; unused wells and salt water collections.

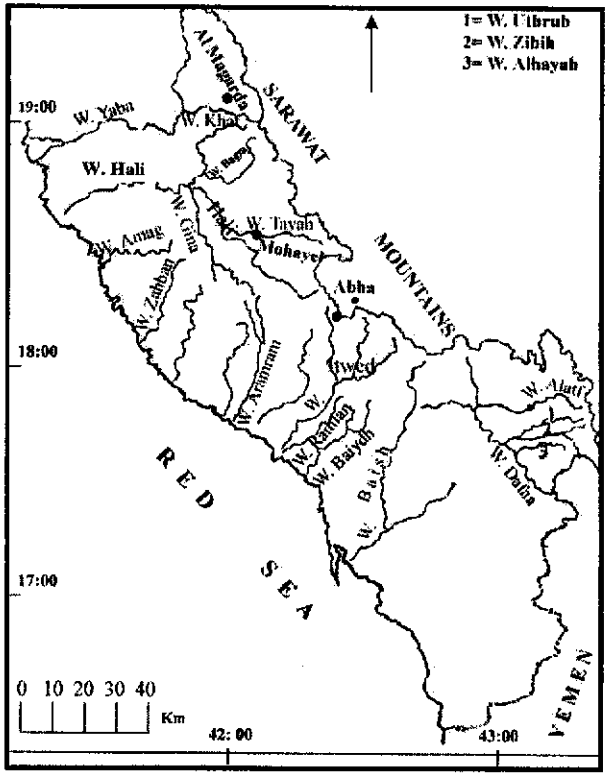

Fig. (1): Main Wadis surveyed for Mosquito breeding habitats in Tihama lowlands of Asir region, Kingdom of Saudi Arabia

In Wadis water flow is directed by channel systems into field units, and new areas are flooded sequentially. Together with the rainfall, this results in many large and small water pools suitable for breeding of certain mosquito species that are believed to be of greatest importance in amplifying and transmitting the RVF virus and malaria parasites. Mosquito larvae were found in numerous habitats. The relative value of each habitat as a mosquito breeding source are shown in table (1).

Running and Semi-stagnant water:

Few mosquitoes were found in running and semi-stagnant water habitats. Only 23 from 3773 surveyed sites (0.6 %) supported mosquito breeding. In this

type of habitats larvae can be flushed out when stream volume increases, and to remain in the stream they require a large amount of energy. *Anopheles d'thali, An. turkhudi , Culex sainiticus and Culesita spp.* have all been found in semi-stagnant water streams (table 2), although they may prefer other habitats. These species can anchor themselves on the vegetation along banks or attempt to remain away from the main flow of the stream by seeking isolated eddies.

Permanent and semi-permanent water:

In Wadis, Permanent and semi-permanent water are the main sites for mosquito breeding. Generally this habitat shows water quality changes which results in various mosquito species using the same pool over a period of time. The relationship between rainfall on the mosquito population dynamics is well established and has been modeled accordingly (Craig *et al.*, 1999). Following heavy rains and floods the water becomes highly turbid and used as breeding grounds for many species of mosquitoes. Four anopheline and 5 culicine species were found breeding in turbid water and *Cx. duttoni* was the highly abundant species in this habitat (table, 2). These results disagree with what have been found by Sattler *et al.*, 2005. The authors concluded that turbid water diminishes the breeding chance of the *Anopheles sp.* The authors also noticed that turbid breeding sites were much less likely to contain high densities of anopheline larvae. In our study four anopheline species were found with moderate densities in turbid habitats (table 2). In another study (Ye-Ebiyo *et al.*, 2003) found that the production of *An. arabiensis* was favored in moderately turbid water, while excessive turbidity limited the production of larvae. This contradiction may be attributed to difference in the definition of "turbidity". Water which is turbid from particles not edible for *Anopheles sp.* larvae could disfavor the production of larvae, while water turbid from food particles represents a very suitable habitat (Sattler *et al.*, 2005).

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Few days following rains and/or floods , the water becomes so clear and attracts other mosquito species, which seem to prefer clear water such as *An. multicolor, An. d'thali, Cx. sinaiticus, Cx. tritaeniorhynchus* and *Cx. laticinctus* which were the highly abundant species in this habitat (table 2). The growth of algae and vegetations in water may favor the breeding of many species of mosquitoes, especially *An. sergenti, An. rupicolus, An. turkhudi*, Cx. *bitaeniorhynchus* and *Cx. tritaeniorhynchus.* The presence of *An. sergenti* in places with aquatic vegetations and algae in Asir region was also recorded by Abdullah and Merdan (1995). Certain mosquito species as *An. d'thali, Cx. tritaeniorhynchus and Cx. tigripes* were abundant in almost all types of Permanent and semi-permanent water habitats. In many cases, stagnant water becomes polluted with organic materials from plant or animal origins. Polluted water in wadis breeds species known to prefer polluted water as *Cx. tritaeniorhynchus* (high abundance) and *Cx. tigripes* (moderate abundance). In this type of habitat *An d'thali* and *Cx. pipiens* complex were found in low abundance.

In arid habitats and at the edge of Wadis the soil is dry and rocky and doesn't retain water for long time. After a flooding rain, temporary and shallow water collections were found. These water collections are used as breeding grounds for mosquito species whose eggs can withstand desiccation, and their life cycles require alternating periods of wet and dry (Miller *et al.*, 2002). In our study these collections were found to hold enormous numbers of *Aedes vexans arabiensis*, which is the proved vector of RVF in the area (Miller *et al.*, 2002). The species was also collected from many agriculture water catchments (table 2).

Small clear water collections as man made small ditches, water in animal hoof pads and rock pockets supported the breeding of a limited number of mosquito species as *An. arabiensis, An. sergenti, An. d'thali* and *Cx. sinaiticus*

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(table 2). Although these places are small in size and usually contain small amount of water, most of them contained high larval density.

High percentage (38.39%) of the artificial water containers such as discarded tires and tins supported mosquito breeding. Tire piles and tins, which are numerous in many instances, can breed enormous numbers of mosquitoes. In addition to *Ae vittatus*; the yellow fever mosquito *Ae. aegypti* was found only in these specific habitats throughout the whole period of our study. High larval density in these habitats can be attributed to the nature of water, which suits the breeding of specific mosquito species, and/or the insulation it provides against unsuitable weather conditions.

Cement basins made for animals drinking are widely distributed in the area and was found an important breeding habitat for many species of *Anopheles* and *Culex* mosquitoes as well as *Ae. vittatus*. About 71% of basins surveyed supported mosquito breeding (table 1). Similarly 32.43% of plastic barrels used for animals drinking were positive for anopheline and Culicine mosquitoes. In ground pools, predators are typically thought to regulate the density of mosquito larvae (Washburn, 1995 and Sunahara *et al.*, 2002). Predators may exert an effect by consuming larvae or through deterring oviposition into an otherwise suitable habitats (Angelon and Petranka, 2002). Widely disturbed, man-made habitats such as cement basins and plastic barrels provide a developmental habitat in which mosquito larvae escape the high degree of predation found in the natural environment. These habitats should be specifically targeted during larval control programs.

Only 7.42% of house hold water tanks supported mosquito breeding (table 1). High percentages of the cesspits surveyed (61.9%) were positive for one species of mosquito namely *Cx. pipiens* complex (table 2). The prevalence of this species in cesspits may indicate that his species can survive in waters with high organic content (Abdullah and Merdan, 1995).

Abandoned wells are widely distributed in the area, and many of them (35.9%) were positive for *An. turkhudi, Cx. pipiens* complex *and Cx. sinaiticus.*

Only one species of mosquito; namely *Cx. sitiens* was collected from 27.27% of salt-water collections surveyed.

Twenty mosquito species were identified; Seven anopheline species *(An. d'thali, An. rupicolus, An. arabiensis, An. sergentii, An. multicolor, An. turkhudi* and *An. pretoriensis*0; eight culicine species (Cx. *pipiens* complex, *Cx. sinaiticus* , Cx. *tritaeniorhynchus Cx. bitaeniorhynchus. Cx. sitiens, Cx. duttoni and Cx. tigripes),* four aedine species *(Ae. vexans arabiensis, Ae vittatus, Ae. aegypti* and *Ae. caballus*) and *Culesita spp.* In an earlier study Abdullah and Merdan (1995) collected only nine species from the same area, 3 of them were not found in our collection.

An. d'thali, An. sergenti, An. arabiensis, Cx sainiticus, Cx. tritaeniorhynchus were the most abundant anopheline and culicine species in most surveyed habitats (table 2). The wide distribution of *An. sergenti, An. arabiensis* in the study area was also reported by Abdullah and Merdan (1995). Meanwhile *An. d'thali* and *Cx. sinaiticus* which were not collected by the previous authors were found as the predominant anopheline and culicine species in our study. This contradiction may be attributed to the difference in sampling locations. The prevalence of *Aedes vexans arabiensis* and *Ae. vittatus* in the area of study was also reported by (Miller *et al.,* 2002) whereas Abdullah and Merdan (1995) collected only another aedine species namely *Ae. caspius.*

The statistical analysis of data shows that most species of mosquitoes can breed in almost all natural water accumulations in Wadis of the study region with different chemical characteristics. For every chemical parameter identified as enhancing or reducing mosquito larvae productivity, at least one breeding site was found that contradicted these findings. Hence, all water bodies in the

environment should be considered as potential breeding places and a target for larval control.

The seasonal variations in habitat availability and larval productivity of mosquito breeding habitats in Wadis of Mohayel and Al-Magarda are presented in table (3). In this part of study, mosquitoes were not classified down to species level. The goal of the study was to characterize the seasons with high mosquito productivity, regardless of the species. This is because in the context of sustainable operations in a routine mosquito abatement program, municipal staff cannot be expected to identify all mosquito larvae samples to species level without rendering sampling procedures prohibitively laborious and expensive (Sattler *et. al.*, 2005). To achieve a satisfactory impact, exhaustive targeting of all potential vector species is necessary anyway. Furthermore, community acceptance of vector control programs has been shown to require suppression of all mosquito species, rather than only specific vectors (Sunahara *et al.*, 2002).

Both rainfall and temperature regimes influence the number and duration of water pools (Fischer *et al.*, 2002). As already observed by Fischer *et al.* (2000), periods with similar accumulated rainfalls but different temperatures, differed markedly in the number of rain pools formed, owing to a rapid absorption of water by the dry ground together with an accelerated evaporation at higher temperatures. The combined effects of rain, air temperature, evaporation, transpiration and soil water balance are linked to the maintenance of breeding places (Casanova and Prado, 2002). The number of mosquito aquatic habitats was highly variable either among seasons or between consecutive months. A significant increase in habitat availability was observed during winter and spring seasons of the year 2000-2001 and winter of the second year 2001-2002. The minimum number of aquatic habitats was found during summer and autumn seasons of the first year and during spring and summer seasons of the second year of study. It seems that the increase in

number of mosquito breeding habitats in winter is due to the amount of rains and a heavy flood in December, whereas the high number of habitats recorded in the spring of the first year of study is due to floods in March and April. The low number of habitats recorded during summer was associated with high temperature and drought. No significant difference was found between the number of positive pools in different seasons (table 3). The year-round presence of immature mosquitoes indicates that the climatic conditions of the area are not limiting to the development of most prevailing mosquito species.

The statistical analysis of data showed a week positive correlation between the total number of breeding places inspected and the number of positive pools for anopheline mosquitoes. A week negative correlation was found between the total number of breeding places inspected and the number of positive pools for culicine mosquitoes (table 4). The total relative abundance of anopheline and culicine larvae showed a significant positive correlation with the number of mosquito- pools inspected. In spite of the significant increase in the number of *Culex* larvae in winter and spring seasons in the first year of study, mosquito larvae were abundant throughout the four seasons. Although high temperature in summer may be unfavorable to larval development, mosquito larvae were found in all seasons.

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Table (1): Mosquito larval habitats surveyed in Tihama lowlands, Asir region, Saudi Arabia

Type of the breeding habitat	No of habitats inspected	Habitats +ve for mosquitoes	
		Number	%
Wadis:-			
+ Semistagnant water	3773	23	0.6
+ Stagnant water:-			
- Clear	1831	120	6.55
- Clear with vegetations	547	77	14.08
- Clear with algae	320	63	19.69
- Turbid	1629	970	59.5
- Polluted	781	432	55.31
Man made small ditches	177	28	15.82
Water in animal hoof pads	93	10	10.75
Water in rock pockets	421	8	0.02
Temporal rain pool collections	381	41	10.76
Cement basins for animal drink	621	441	71.01
Household water tanks	431	32	7.42
Agriculture water catchment	120	17	14.16
Cespets	63	39	61.9
Water in discarded tyres & tins	112	43	38.39
Plastic barrels for animal drink	37	12	32.43
Abandoned wells	39	14	35.9
Salt water collections	33	9	27.27
Total	**11409**	**2379**	**20.85**

Table (2): Abundance of mosquito larvae in different larval habitats surveyed in Tihama lowlands, Asir region, Saudi Arabia

Type of the breeding habitat	*Anopheles*							*Culex*							*Aedes*					*Culesita*
	arabiensis	*sergentii*	*d'thali*	*rupicolus*	*multicolor*	*turkhudi*	*pretoriensis*	*tritaeniorhynchus*	*sainiticus*	*pipiens* complex	*duttoni*	*laticinctus*	*bitaeniorhynchus*	*sitiens*	*tigripes*	*aegypti*	*vittatus*	*arabiensis*	*caballus*	*spp.*
Wadis																				
Semi-stagnant water			c			b			b											c
Stagnant water																				
Clear	b	b	c		c		b	c	d		b	c	b		b					b
Clean with vegetations		c	b	c		c		c					c		b					
Clean with algae			b			d		c					d		b					
Turbid	c	b	c				c	b	c		d	c			b					
Polluted			b					d	a	b					c					
Man made small ditches	b	b	c	a					c											
Water in animal hoof pads	b	b	c						c											
Water in rock pockets	b		c					b	b											
Temporal rain pool collections	c	b	c					b	c									d		
Cement basins for animal drink	a	c	c	b				b	c		b	b					c		a	
Household water tanks		c	b						b									b		
Agriculture water catchment								c												
Cesspits										d										
Water in discarded tyres & tins																d	c			
Plastic barrels for animal drink		c	b	b					b			b								
Unused Wells						b			b	c										
Salt water collections														d						

Larval abundance: a = rare (larvae in only 1 out of 10 dips) b = low (larvae in 2 or 3 out of 10 dips)
c = medium (larvae in 4 or 6 out of 10 dips) d = high (larvae in more than 6 out of 10 dips)