

Distribution and Seasonal Abundance of Different Mosquito Species (Diptera: Culicidae) in Al Bahah Region, Saudi Arabia

الكثافة العددية وتوزيع البعوض (Diptera : Culicidae) في منطقة الباحة بالمملكة العربية السعودية

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Abstract: This study was conducted in Al Bahah Region, Kingdom of Saudi Arabia during the period from March 2004 to February. 2006, to determine mosquitoes fauna and their abundance. Results showed that there are 19 mosquito species belonging to four genera. The identified species include *Aedes vexans arabiensis*, *Ae. caspius*, *Ae. aegypti*, *Anopheles cinereus*, *An. d'thali*, *An. stephensi*, *An. subpictus*, *An. turkhudi*, *Culex laticinctus*, *Cx. perexiguus*, *Cx. pipiens*, *Cx. quinquefasciatus*, *Cx. sinaiticus*, *Cx. theileri*, *Cx. tigripes*, *Cx. torrentium*, *Cx. tritaeniorhynchus*, *Cx. univittatus* and *Culiseta longiareolata*. Most larvae identified belonged to *Culex* sp. (50.35%), followed by *Anopheles* spp. (38.41%) and *Culiseta* sp. (11.24%). The results showed no significant correlation between total dissolved salts (TDS) and pH of the water and the distribution of different mosquito larvae species. Adult mosquitoes were collected throughout the year, but at different magnitudes, depending on prevailing climatic conditions. Adult population began to increase in April to May with the increase in temperature at the end of the winter season, reaching a peak in June, with an average temperature of 29° C and average monthly rainfall below 10 mm. However, the population density of adults declined gradually in the period between August and September, reaching minimum density in November with an average temperature of about 18° C. This study confirmed the presence of *Cx. tritaeniorhynchus*, the main vector of Rift Valley fever, in Al Bahah Region for the first time. The presence of this disease vector constitutes a major health problem, and every effort should be made to control it. The results of this study have shown that mosquitoes are widespread in Al Bahah Region. Further studies on their medical impact and vectorial capacity in disease transmission are required.

Keywords: mosquito, *Culiseta*, Al-Bahah, Saudi Arabia

المستخلص: تم إجراء حصر للبعوض في منطقة الباحة بالمملكة العربية السعودية خلال الفترة من مارس 2004م حتى فبراير 2006م، وقد تم جمع 19 نوع من البعوض تنتمي لأربعة أجناس وهي: ثلاثة أنواع *Aedes*، خمسة *Anopheles*، عشرة *Culex* ونوع واحد *Culiseta* وهذه الأنواع هي: *Aedes vexans arabiensis*, *Ae. caspius*, *Ae. aegypti*, *Anopheles cinereus*, *An. d'thali*, *An. stephensi*, *An. subpictus*, *An. turkhudi*, *Culex laticinctus*, *Cx. perexiguus*, *Cx. pipiens*, *Cx. quinquefasciatus*, *Cx. sinaiticus*, *Cx. theileri*, *Cx. tigripes*, *Cx. torrentium*, *Cx. tritaeniorhynchus*, *Cx. univittatus* and *Culiseta longiareolata*.

معظم يرقات البعوض التي تم حصرها تنتمي لجنس *Culex* وكانت تمثل 50.35% ، يليها جنس *Anopheles* وتمثل 38.41% و جنس *Culiseta* بنسبة 11.24% . معظم اليرقات جمعت من المياه الراكدة أو البطيئة الجريان في قنوات الري، ومن خزانات المياه ومن تجمعات المياه التي بها طحالب، وأوضحت الدراسة أنه لا يوجد علاقة معنوية بين الأملاح المذابة (TDS) أو درجة الحموضة (pH) من جهة وبين توزيع وانتشار يرقات البعوض في المياه ولوحظ زيادة أعداد الحشرات البالغة في شهري أبريل ومايو مع زيادة درجات الحرارة وكانت القمة في شهر يونيو عندما كان متوسط درجات الحرارة 29م° ومتوسط كمية الأمطار الشهري أقل من 10 ملم، ثم بدأت الأعداد بالانخفاض في شهري أغسطس وسبتمبر حتى أصبحت أعدادها قليلة جدا في شهر نوفمبر عندما كان متوسط درجات الحرارة أقل من 18م° . إن وجود بعوض *Cx. tritaeniorhynchus* - وهو الناقل الرئيس لحمى الوادي المتصدع في جنوب المملكة - في منطقة الباحة يهدد بانتشار هذا المرض في منطقة الباحة ولذا نوصي بمكافحة هذه الحشرة لمنع انتشار هذا المرض، كما أوضحت هذه الدراسة وجود 19 نوع من البعوض في منطقة الباحة ولذا يجب القيام بمزيد من الدراسات لمعرفة الأهمية الطبية لهذه الأنواع من البعوض وكفاءتها في نقل الأمراض قبل البدء في مكافحتها.

كلمات مدخلية: البعوض، *Culicidae*، الباحة، المملكة العربية السعودية.

INTRODUCTION

In the past few decades, the Kingdom of Saudi Arabia has witnessed a tremendous efforts in social development and urbanization in all its provinces, which has indirectly affected the insect fauna, particularly mosquitoes (Diptera: Culicidae). The expansion of agricultural projects, urbanization and development of water resources, in addition to the favorable climatic conditions for mosquito survival and development in the Al Bahah Region, have all led to the creation of both permanent and temporary breeding sites for mosquitoes.

The distribution of mosquitoes species in Saudi Arabia has been investigated by many researchers. Mattingly and Knight (1956) studied the distribution of mosquito larvae in the Arabian Peninsula and recorded 46 mosquito species and subspecies. In Saudi Arabia, they recorded *Aedes aegypti*, *Ae. arabiensis*, *Ae. caspius*, *Anopheles cineris*, *An. multicolor*, *An. stephensi*, *An. coustani*, *An. turkhudi*, *An. gambiae*, *An. sergenti*, *Culex laticinctus*, *Cx. tritaeniorhynchus*, *Cx. sitiens*, *Cx. sinaiticus*, *Cx. pusillus*, *Cx. tigripes*, *Cx. pipiens* and *Culiseta longiareolata*. In the Eastern Region of Saudi Arabia, Wills, et al. (1985) collected *Ae. caspius*, *An. fluviatilis*, *An. sergenti*, *An. tenebrosus*, *Cx. pipiens*, *Cx. quinquefasciatus*, *Cx. tritaeniorhynchus*, *Cx. univittatus*, *Uranotaenia unguiculata* and *Cs. longiareolata*. In another study in the Southwestern region of Saudi Arabia, Abdullah and Merdan (1995) recorded nine mosquito species: *Ae. caspius*, *An. arabiensis*, *An. multicolor*, *An. sergenti*, *An. tenebrosus*, *Cx. pipiens*, *Cx. quinquefasciatus*, *Cx. theileri* and *Cs. subochrea*.

The malaria vectors in Saudi Arabia were also studied by many researchers. In the Western Region of Saudi Arabia, Al Ghamdi, et al. (2008) reported 11 species of malaria which included *An. d'thali*, *An. culicifacies*, *An. gambiae*, *An. turkhudi*, *An. pharoensis*, *An. sergenti*, *An. multicolor*, *An. fluviatilis*, *An. subpictus*, *An. stephensi* and *An. rhodesiensis*. Abdoon and Al Shahrani (2003) reported seven species of anopheline mosquitoes in the Asir Region: these were: *An. d'thali*, *An. rupicolus*, *An. sergenti*, *An. arabiensis*, *An. multicolor*, *An. turkhudi* and *An. pretoriensis*. The ecology of malaria vectors in Saudi Arabia was studied by Zaher (1973).

During the 2000 epidemic of Rift Valley Fever in the southern region of Saudi Arabia, Jupp, et al. (2002) and Miller, et al. (2002) collected seven species of mosquitoes: *Ae. vexans arabiensis*, *Cx. tritaeniorhynchus*, *Ae. vittatus*, *An. azaniae*, *Cx. pipiens*, *Ochlerotatus caballus* and *Ochlerotatus caspius* and isolated the Rift valley Fever virus from *Ae. vexans arabiensis* and *Cx. tritaeniorhynchus*. During a recent study of adult mosquitoes in the Riyadh Region, Al Khereji et al. (2007) recorded the following species: *Ae. caspius*, *An. stephensi*, *An. coustani*, *An. d'thali*, *An. pretoriensis*, *Cx. laticinctus*, *Cx. perexguus*, *Cx. pipiens*, *Cx. quinquefasciatus*, *Cx. simpsoni*, *Cx. sinaiticus*, *Cx. theileri*, *Cx. tritaeniorhynchus*, *Cx. univittatus* and *Cs. longiareolata*. The distribution of mosquitoes in the Riyadh Region has been also studied by Buttiker (1981) and Alahmed, et al. (2007). Although several researchers have studied the distribution of mosquitoes in Saudi Arabia, scanty information is available on the mosquito

fauna of the Al Bahah Region. The present study has been undertaken to examine the distribution of mosquitoes in the Al Bahah Region

MATERIAL AND METHODS

The Study Area

Al Bahah Region is situated in the southwestern area of Saudi Arabia, between longitudes $41^{\circ} 13'$ / $42^{\circ} 35'$ E, and latitudes $19^{\circ} 25'$ / $21^{\circ} 35'$ N (Figure 1). The Region is comprised of mountains, plains, hills, valleys and desert stretches, divided by huge rocky steeps into two sectors. To the west is a coastal plain (Tihamah), while to the east is a mountain range of Al Sarawat (known as Al Sarat) with an elevation of 1500 - 2450 meters above sea level. The climate in the Al Bahah Region is influenced by the topography of the region. In Al Sarat, winter is cold while spring and summer are mild and pleasant. Tihamah is hot in summer, warm in spring and mild in winter. The relative humidity varies between 52% - 67%, with a maximum and minimum temperature of 23° C and 12° C respectively.

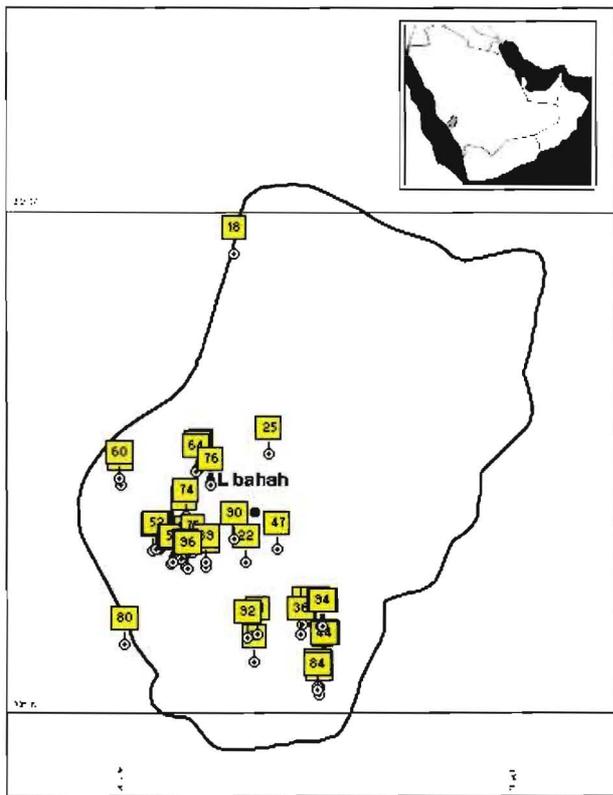


Fig. 1. Collection sites of mosquitoes in the Al Bahah Region, Saudi Arabia.

Larval Collection

Collection was undertaken for two successive years, from March 2004 to February 2006. Weekly field trips were made to collect mosquito larvae from all potential breeding sites in the Al Bahah Region (Figure 1). The larvae were collected using a standard mosquito larval dipper with an extendable handle, and three to five scoops were taken from each breeding site (350 ml each). Larvae were extracted and preserved using 80% ethyl alcohol in glass vials with screw caps, packed, labeled and shipped to the Entomology laboratory, College of Food and Agricultural Sciences, King Saud University, Riyadh. Larvae were mounted as prescribed by R.E. Harbach from the Natural History Museum in London *(personal Communication), and identified using standard identification keys (Hopkins 1952; Mattingly and Knight 1956; Harbach 1988 and Al-Tubiakh 1995). Representative samples of identified larvae were sent to the British Natural History Museum in London for confirmation.

At each breeding site, the following information was recorded: date and time of larval collection, coordinates of the breeding site using Global Positioning System device (GPS), current weather conditions, water temperature, pH and total dissolved salts (TDS in ppm) of water, degree of water turbidity and motion, category of breeding site (e.g. irrigation canals, rain water collections, ponds, septic tank or water storage tanks) and the presence or absence of algae and aquatic plants.

Adult Collection

Adult mosquitoes were collected using one Center for Disease Control miniature light trap (CDC light traps) and one standard New Jersey (NJ) light trap (Bioquip Company, Gardena, CA, 90248-3602, USA). The CDC and the NJ light traps were attached to a battery supply which was installed permanently near suitable mosquito breeding sites. Light traps were operated once every two weeks from sunset to sunrise the following day throughout the study period. Collected adult mosquitoes were packed, labeled and transported to the Entomology Laboratory in Riyadh. Adult mosquitoes were identified using standard identification keys of Mattingly

and Knight (1956); Harbach (1988); Glick (1992) and Al-Tubiakh (1995). Representative samples of identified mosquitoes were sent to the British Natural History Museum in London for confirmation. The mean monthly temperature and relative humidity during the study period was obtained from the National Centre for Meteorology, Riyadh. Pearson correlation coefficient (r) was used to study the effects of pH and TDS on the distribution of different mosquito larvae at 0.05 level (SAS, 2001).

RESULTS

Identification of 4,980 adults and larval mosquitoes collected in this study revealed that there are 19 species spread throughout the Al Baha Region belonging to four genera: *Aedes vexans arabiensis*, *Ae. caspius*, *Ae. aegypti*, *Anopheles cinereus*, *An. d'thali*, *An. stephensi*, *An. subpictus*, *An. turkhudi*, *Culex laticinctus*, *Cx. perexiguus*, *Cx. pipiens*, *Cx. quinquefasciatus*, *Cx. sinaiticus*, *Cx. theileri*, *Cx. tigripes*, *Cx. torrentium*, *Cx. tritaeniorhynchus*, *Cx. univittatus* and *Culiseta longiareolata*.

Out of 4,304 mosquito larvae collected from the study area (Table 1), *Culex* larvae were the most abundant (50.35%), followed by *Anopheles* (38.41%) and *Culiseta* (11.24%). Most of the larvae were collected from stagnant or slowly running irrigation canals with submerged or floating aquatic plants, grassy or slightly shaded water pools and water storage tanks. Larvae were also collected from temporary or permanent brackish polluted water, septic tanks, drainage water collections with algae and from abandoned wells. All distribution and collection

sites of mosquito larvae are shown in Table (2).

A study of the physical properties of water from the larval breeding sites revealed that the TDS varied between 128 ppm to 1856 ppm, pH ranged from 7.3 – 10.5, and water temperature varied between 15.5° C during winter and 33.7° C during summer. The results showed that no significant correlation between pH and distribution of different mosquito larvae ($r = 0.047$, $P > 0.05$). Similarly, results indicated no significant correlation between TDS and distribution of different mosquito larvae ($r = 0.082$, $P > 0.05$).

Out of 676 adult mosquitoes collected (Table 3), CDC light collected 374, while 302 adults were caught by NJ light trap. Of all adult mosquito species collected, *Culex* was the most abundant (73.08%), followed by *Anopheles* spp. (23.37%), *Aedes* spp. (3.11%) and *Culiseta* sp. (0.44%) respectively.

Adult mosquitoes were collected throughout the year, but in different densities depending on prevailing climatic conditions (Figure 2). The population activity of adult mosquitoes started to increase during the period April through May, with increase in temperature after the end of the winter season, reaching a peak in June with a mean monthly temperature of 29° C. The mosquito population started to decline during the period of August through September, and reached minimum activity in November when the temperature was about 18° C. Mosquito activity is closely linked with the rainfall. The high level of rains started in April providing more breeding sites for mosquitoes, and a higher peak of activity was attained in June (Figure3).

Table 1. Species of mosquito larvae collected from the Al Bahah Region, of Saudi Arabia from March 2004 to February 2006.

Date	<i>Culiseta</i>		<i>Culex</i>					<i>Anopheles</i>			Total
	<i>longiareolata</i>	<i>univittatus</i>	<i>tritaeniorhynchus</i>	<i>tigripes</i>	<i>pipiens</i>	<i>perexiguus</i>	<i>turkhudi</i>	<i>subpictus</i>	<i>stephensi</i>	<i>d-thali</i>	
Mar 2004	27	12	0	0	1	29	74	0	0	0	143
Apr 2004	100	0	0	0	161	0	0	0	0	0	261
May 2004	0	14	0	0	68	34	0	0	0	0	116
Jun 2004	0	11	0	0	63	80	0	0	0	0	154
Jul 2004	0	37	0	0	18	1	0	0	0	17	73
Aug 2004	0	0	0	0	0	100	3	0	0	9	112
Sep 2004	0	56	0	0	0	8	0	0	0	0	64
Oct 2004	0	0	0	0	15	0	313	0	0	0	328
Nov 2004	0	0	0	0	0	0	0	536	0	0	536
Dec 2004	0	3	0	0	0	0	0	1	0	0	4
Jan 2005	0	0	0	0	0	0	0	0	0	476	476
Feb 2005	0	51	177	0	0	0	0	0	0	0	228
Mar 2005	0	0	185	0	0	0	0	0	0	10	195
Apr. 2005	0	5	170	0	0	0	0	0	0	0	175
May 2005	0	9	0	0	9	0	0	2	0	0	20
Jun 2005	0	60	0	0	1	0	0	52	0	0	113
Jul 2004	0	92	0	0	35	0	0	0	0	15	142
Aug 2005	0	174	37	9	0	0	0	0	0	6	226
Sep 2005	0	25	0	0	0	0	0	0	33	0	58
Oct 2005	0	76	10	0	0	0	0	56	0	0	142
Nov 2005	0	131	72	0	0	0	0	27	0	7	237
Dec 2005	0	49	22	0	0	0	0	16	0	0	87
Jan 2006	18	57	0	0	0	0	0	0	0	0	75
Feb 2006	339	0	0	0	0	0	0	0	0	0	339
Total	484	862	673	9	371	252	390	690	33	540	4304

Table 2. Collection sites of mosquito larvae in the Al Bahah Region, Saudi Arabia.

Site No.	Date	Coordinates (N°, E°)		Mosquito Larvae Species Collected		
1	08/01/1425	20.10803	41.53787	<i>Cx. pipiens</i>	<i>Cs. longiareolata</i>	<i>An. turkhudi</i>
2	12/01/1425	20.10645	41.53497	<i>An. turkhudi</i>	<i>Cs. longiareolata</i>	
3	19/01/1425	20.05271	41.52329	<i>Cx. univittatus</i>	no larvae collected	
4	26/01/1425	20.17840	41.48473	<i>Cx. perexiguus</i>		
5	03/02/1425	20.31795	41.19131	<i>Cs. longiareolata</i>	<i>Cx. pipiens</i>	
6	10/02/1425	20.31790	41.19126	<i>Cs. longiareolata</i>	<i>Cx. pipiens</i>	
7	17/02/1425	20.31319	41.16299	<i>Cx. pipiens</i>		
8	24/02/1425	20.30708	41.18417	<i>Cs. longiareolata</i>	<i>Cx. pipiens</i>	
9	09/03/1425	20.06904	40.54614	<i>Cx. pipiens</i>		
10	16/03/1425	20.06882	40.54767	<i>Cx. perexiguus</i>		
11	23/03/1425	20.06893	40.54393	<i>Cx. pipiens</i>		
12	30/03/1425	20.13754	41.03664	<i>Cx. univittatus</i>	<i>Cx. pipiens</i>	
13	07/04/1425	20.49203	41.22835	<i>Cx. perexiguus</i>	<i>Cx. pipiens</i>	
14	07/04/1425	20.49343	41.22990	<i>Cx. perexiguus</i>	<i>Cx. pipiens</i>	
15	14/04/1425	20.31295	41.15905	<i>Cx. perexiguus</i>	<i>Cx. pipiens</i>	
16	21/04/1425	20.31011	41.17618	<i>Cx. univittatus</i>	<i>Cx. pipiens</i>	
17	05/05/1425	20.30237	41.24294	<i>Cx. univittatus</i>	<i>Cx. pipiens</i>	
18	12/05/1425	20°34.920	41.31255	<i>Cx. univittatus</i>	<i>Cx. pipiens</i>	
19	19/05/1425	20.15821	41.37246	<i>An. dthali</i>	<i>Cx. pipiens</i>	
20	26/05/1425	20.15033	41.34703	<i>Cx. pipiens</i>	<i>Cx. perexiguus</i>	<i>An. dthali</i>
21	04/06/1425	20.10427	41.36536	<i>An. dthali</i>	<i>An. turkhudi</i>	<i>Cx. perexiguus</i>
22	11/06/1425	20.30237	41.34389	<i>An. dthali</i>	<i>An. turkhudi</i>	
23	18/06/1425	20.30237	41.24294	<i>Cx. perexiguus</i>		
24	25/05/1425	20.29354	41.24252	no larvae collected		
25	02/07/1425	19.51804	41.39962	no larvae collected		
26	09/07/1425	20.10805	41.54018	<i>Cx. univittatus</i>		
27	16/07/1425	20.10802	41.53931	<i>Cx. univittatus</i>		
28	23/07/1425	20.17618	41.53875	<i>Cx. perexiguus</i>		
29	08/08/1425	20.29024	41.19532	<i>Cx. pipiens</i>		
30	15/08/1425	20.29266	41.18975	<i>Cx. pipiens</i>		
31	22/08/1425	20.17579	41.53623	<i>An. turkhudi</i>		
32	29/08/1425	20.17452	41.53352	<i>An. turkhudi</i>		
33	06/10/1425	20.17694	41.51910	<i>An. subpictus</i>		
34	13/09/1425	20.17894	41.51558	<i>An. subpictus</i>		
35	20/09/1425	20.15898	41.48035	<i>An. subpictus</i>		
36	27/09/1425	20.15887	41.48031	<i>An. subpictus</i>		
37	07/10/1425	20.06871	40.54007	<i>Cx. univittatus</i>	<i>An. subpictus</i>	
38	11/10/1425	20.06560	40.54020	no larvae collected		
39	18/10/1425	20.06985	40.53740	no larvae collected		
40	25/10/1425	20.07081	40.53626	no larvae collected		
41	03/11/1425	20.11177	41.54521	<i>An. dthali</i>		
42	10/11/1425	20.11597	41.54559	<i>An. dthali</i>		

Table 2. (Continued) Collection sites of mosquito larvae in Al Bahah Region, Saudi Arabia.

Site No.	Date	Coordinates (N°, E°)		Mosquito Larvae Species Collected		
43	17/11/1425	20.10922	41.54365	<i>An. dthali</i>		
44	24/11/1425	20.10931	41.54225	<i>An. dthali</i>		
45	01/12/1425	19.32815	41.12327	<i>Cx. tritaeniorhynchus</i>		
46	08/12/1425	19.32812	41.12318	<i>Cx. univittatus</i>		
47	15/12/1425	19.32895	41.42362	<i>Cx. univittatus</i>		
48	22/12/1425	19.32787	41.12244	<i>Cx. tritaeniorhynchus</i>		
49	04/01/1426	19.32805	41.11985	<i>Cx. tritaeniorhynchus</i>		
50	11/01/1426	19.32795	41.11812	<i>Cx. tritaeniorhynchus</i>		
51	18/01/1426	19.32501	41.10803	<i>Cx. tritaeniorhynchus</i>		
52	25/01/1426	19.32800	41.11301	<i>Cx. tritaeniorhynchus</i>	<i>An. dthali</i>	
53	06/02/1426	19.45548	41.02589	<i>Cx. tritaeniorhynchus</i>	<i>Cx. univittatus</i>	
54	13/02/1426	19.45615	41.02651	<i>Cx. tritaeniorhynchus</i>		
55	20/02/1426	19.45647	41.02658	<i>Cx. tritaeniorhynchus</i>		
56	27/02/1426	19.45651	41.02642	<i>Cx. tritaeniorhynchus</i>		
57	04/03/1426	20.31801	41.19151	no larvae collected		
58	11/03/1426	20.29970	41.15426	no larvae collected		
59	18/03/1426	20.30112	41.15711	no larvae collected		
60	25/03/1426	19.47044	41.01975	<i>Cx. pipiens</i>	<i>An. subpictus</i>	<i>Cx. univittatus</i>
61	10/04/1426	20.48364	41.21607	<i>Cx. pipiens</i>	<i>An. subpictus</i>	<i>Cx. univittatus</i>
62	24/04/1426	20.48180	41.21600	<i>Cx. univittatus</i>		
63	30/04/1426	20.48804	41.22131	<i>Cx. univittatus</i>		
64	27/04/1426	20.48167	41.21602	<i>Cx. univittatus</i>	<i>An. subpictus</i>	
65	04/05/1426	20.04871	41.52322	<i>Cx. pipiens</i>		
66	11/05/1426	20.04943	41.52394	<i>An. dthali</i>	<i>Cx. univittatus</i>	
67	18/05/1426	20.05121	41.52581	<i>Cx. univittatus</i>		
68	25/05/1426	20.05160	41.52621	<i>Cx. univittatus</i>		
69	03/06/1426	20.03561	41.52714	<i>Cx. tritaeniorhynchus</i>		
70	10/06/1426	20.03746	41.52774	<i>Cx. univittatus</i>		
71	17/06/1426	20.04859	41.52295	<i>Cx. tritaeniorhynchus</i>	<i>Cx. univittatus</i>	<i>An. dthali</i>
72	24/06/1426	20.05236	41.52679	<i>Cx. univittatus</i>	<i>Cx. tigripes</i>	<i>An. dthali</i>
73	05/07/1426	20.37680	41.18424	<i>Cx. univittatus</i>		
74	12/07/1426	20.39517	41.19182	<i>An. stephensi</i>		
75	19/07/1426	19.32270	41.20605	no larvae collected		
76	26/07/1426	19.45537	41.25351	no larvae collected		
77	03/08/1426	20.06094	40.54614	<i>Cx. univittatus</i>	<i>An. subpictus</i>	
78	10/08/1426	20.06882	40.54767	<i>Cx. tritaeniorhynchus</i>	<i>An. subpictus</i>	
79	17/08/1426	20.06893	40.54393	<i>Cx. univittatus</i>	<i>An. subpictus</i>	
80	24/08/1426	20.13754	41.03664	<i>Cx. univittatus</i>	<i>An. subpictus</i>	
81	02/09/1426	20.03741	41.52774	<i>An. dthali</i>	<i>Cx. univittatus</i>	
82	09/09/1426	20.03561	41.52714	<i>Cx. univittatus</i>	<i>An. subpictus</i>	
83	17/09/1426	20.05236	41.52290	<i>Cx. tritaeniorhynchus</i>		

Table 2. (Continued) Collection sites of mosquito larvae in Al Bahah Region, Saudi Arabia.

Site No.	Date	Coordinates (N°, E°)		Mosquito Larvae Species Collected	
84	24/09/1426	20.04859	41.52295	<i>Cx. tritaeniorhynchus</i>	<i>An. subpictus</i>
85	1/10/1426	20.06971	40.54117	<i>Cx. tritaeniorhynchus</i>	<i>An. subpictus</i>
86	14/10/1426	20.06560	40.54020	<i>Cx. univittatus</i>	<i>An. subpictus</i>
87	21/10/1426	20.06985	40.53740	<i>Cx. univittatus</i>	<i>An. subpictus</i>
88	28/10/1426	20.07081	40.53625	<i>Cx. univittatus</i>	<i>An. subpictus</i>
89	05/11/1426	20.30240	41.24301	<i>Cx. univittatus</i>	
90	12/11/1426	20.34950	41.31255	<i>Cx. univittatus</i>	
91	19/11/1426	20.15840	41.37257	<i>Cs. longiareolata</i>	
92	26/11/1426	20.15035	41.34715	<i>Cx. univittatus</i>	
93	07/12/1426	20.17452	41.53352	<i>Cs. longiareolata</i>	
94	14/12/1426	20.17579	41.53623	<i>Cs. longiareolata</i>	
95	21/12/1426	20.29266	41.18975	<i>Cs. longiareolata</i>	
96	28/12/1426	20.29024	41.19532	<i>Cs. longiareolata</i>	

Table 3. Adult Culex collected from Al Bahah Region.

Collection Date	<i>Culex</i>																Subtotal		Total		
	<i>torrentium</i>		<i>sinaiticus</i>		<i>laticinctus</i>		<i>theileri</i>		<i>peregrinus</i>		<i>tritaeniorhynchus</i>		<i>pipiens</i>		<i>quinquefasciatus</i>						
	NJ	CDC	NJ	CDC	NJ	CDC	NJ	CDC	NJ	CDC	NJ	CDC	NJ	CDC	NJ	CDC	NJ	CDC			
Mar 2004	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	5
Apr 2004	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	2
May 2004	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	2
Jun 2004	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1	0	0	13	1	14	
Jul 2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2	
Aug 2004	0	0	0	0	0	0	0	0	1	0	0	0	4	10	0	4	5	14	19		
Sep 2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1		
Oct 2004	0	0	0	0	0	0	0	0	0	0	0	0	3	4	0	0	3	4	7		
Nov 2004	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	0	5		
Dec 2004	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	3		
Jan 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Feb 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Mar 2005	0	10	0	0	0	0	0	0	0	0	0	0	14	0	4	10	18	20	38		
Apr. 2005	0	5	0	0	0	0	4	0	0	0	0	0	0	10	0	0	4	15	19		
May 2005	0	0	0	0	0	1	0	0	0	0	0	1	1	17	0	20	1	39	40		
Jun 2005	0	0	0	0	0	0	0	0	0	0	0	0	3	27	0	0	3	27	30		
Jul 2005	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10		
Aug 2005	0	9	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	12	12		
Sep 2005	0	14	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	15	15		
Oct 2005	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1		
Nov 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Dec 2005	0	13	0	0	0	0	0	0	0	0	0	0	44	17	0	0	44	30	74		
Jan 2006	0	9	0	0	0	0	0	0	0	0	0	0	22	45	0	0	22	54	76		
Feb 2006	0	25	0	0	0	0	0	0	0	0	0	0	42	45	7	0	49	70	119		
Total	0	96	3	3	0	2	4	1	1	0	0	3	151	182	11	37	170	324	494		

Table 3. (Continued) Adult Aedes, Anopheles and Culiseta mosquitoes collected from the Al Bahah Region, Saudi Arabia.

Collection Date	<i>Culiseta longiareolata</i>			<i>Anopheles</i>					<i>Aedes</i>						Subtotal		Total	
	Total Cs	total		Total An.	<i>dithali</i>		<i>cinereus</i>		Total Ae	<i>caspius</i>		<i>aegypti</i>		<i>arabiensis</i>		NJ		CDC
		NJ	CDC		NJ	CDC	NJ	CDC		NJ	CDC	NJ	CDC	NJ	CDC			
Mar 2004	0	0	0	1	0	0	1	0	1	0	1	0	0	0	0	1	1	2
Apr. 2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May 2004	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0	2	2
Jun 2004	0	0	0	128	0	0	99	29	3	0	0	3	0	0	0	102	29	131
Jul 2004	2	1	1	15	0	0	10	5	8	4	2	0	1	0	1	15	10	25
Aug 2004	0	0	0	1	0	0	0	1	4	3	0	1	0	0	0	4	1	5
Sep 2004	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1
Oct 2004	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1
Nov 2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec 2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr. 2005	0	0	0	2	0	0	1	1	1	0	0	1	0	0	0	2	1	3
May 2005	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	2	0	2
Jun 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul 2005	0	0	0	3	0	0	2	1	0	0	0	0	0	0	0	2	1	3
Aug 2005	0	0	0	4	0	0	3	1	0	0	0	0	0	0	0	3	1	4
Sep 2005	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Oct 2005	0	0	0	1	0	1	0	0	1	0	1	0	0	0	0	0	2	2
Nov 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec 2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan 2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb 2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	2	1	158	0	2	117	39	21	7	5	6	2	0	1	132	50	182

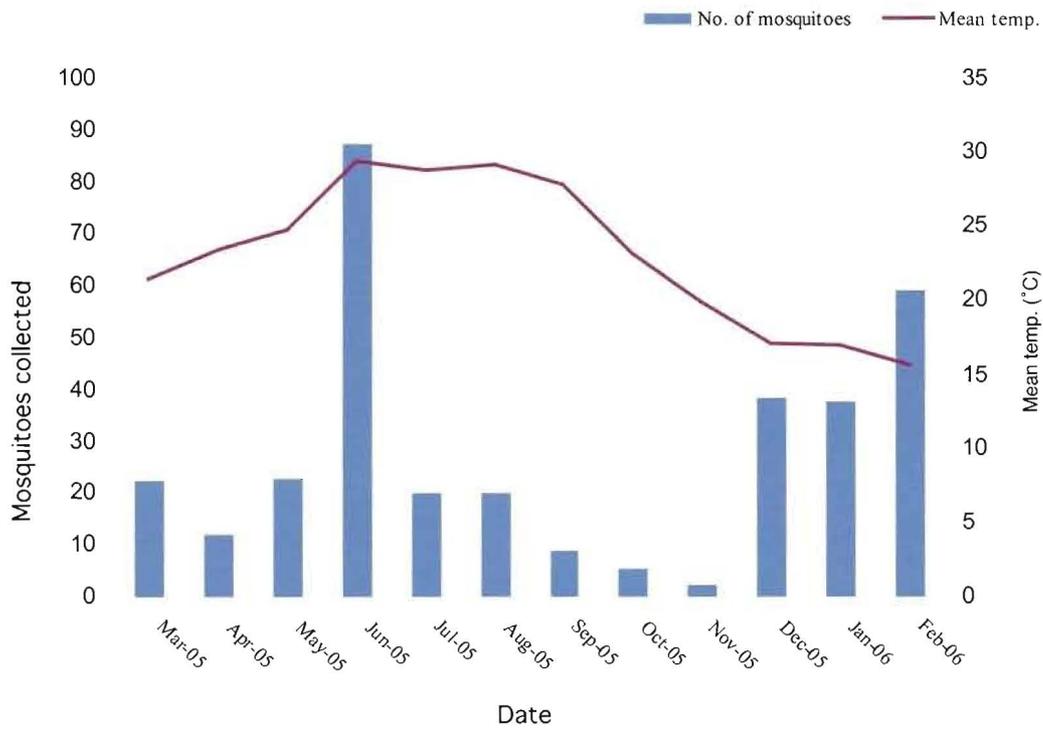


Fig. 2. The effect of temperature on seasonal abundance of mosquitoes in the Al Bahah Region.

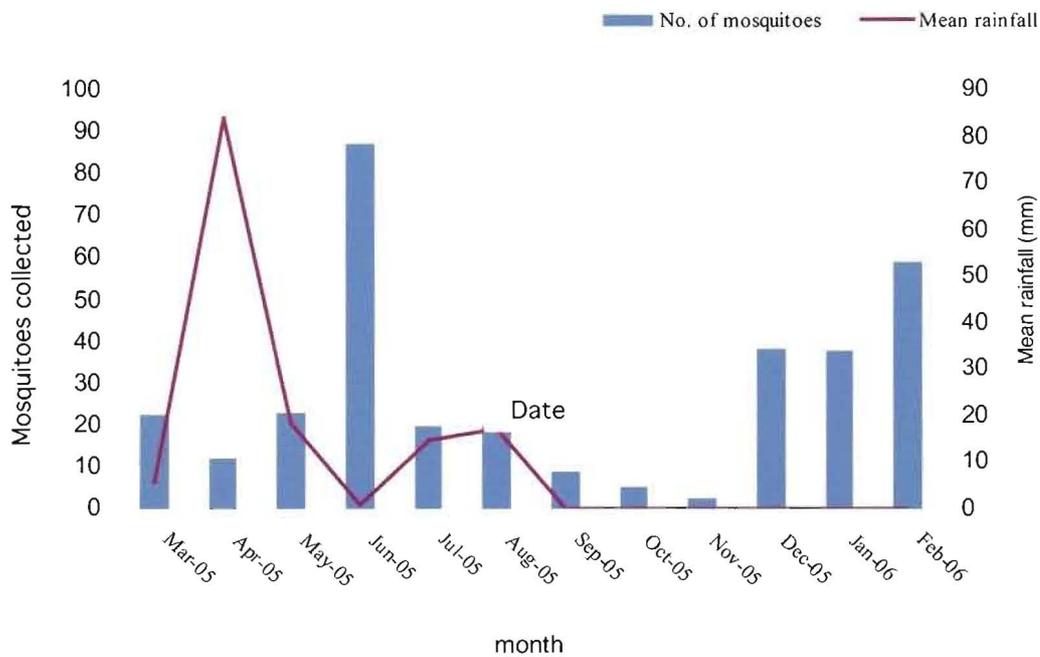


Fig. 3. The effect of rainfall on seasonal abundance of mosquitoes in the Al Bahah Region.

DISCUSSION

In this study, 19 species of mosquitoes were encountered in the Al Bahah Region, and four: *Ae. caspius*, *Cx. pipiens*, *Cx. quinquefasciatus* and *Cx. theileri* were reported earlier in this region (Abdullah and Merdan, 1995). The remaining 15 species: *Ae. vexans arabiensis*, *Ae. aegypti*, *Anopheles cinereus*, *An. d'thali*, *An. stephensi*, *An. subpictus*, *An. turkhudi*, *Cx. laticinctus*, *Cx. perexiguus*, *Cx. sinaiticus*, *Cx. tigripes*, *Cx. torrentium*, *Cx. tritaeniorhynchus*, *Cx. univittatus* and *Cs. longiareolata* were reported for the first time in the Al Bahah Region in this study. Mattingly and Knight (1956) reported some of these species (*Anopheles cinereus*, *An. turkhudi*, *An. stephensi*, *Cx. laticinctus*, *Cx. tritaeniorhynchus* and *Cs. longiareolata*) in other parts of Saudi Arabia.

Culex larvae were the most abundant and were collected from various habitats. The high density of *Culex* larvae might be due to the fact that they can exploit a wide variety of aquatic habitats for their development and survival and can tolerate a highly polluted aquatic environment with relatively saline water. In addition, the presence or absence of shade or aquatic vegetation and degree of water motion and turbidity could be other factors influencing the suitability of the various types of aquatic habitats for mosquitoes.

Culex tritaeniorhynchus, *Ae. aegypti* and *Cx. univittatus* have been reported to be the main vectors of the Rift Valley Fever virus in the southern area of Saudi Arabia (Miller, et al. 2002 and Jupp, et al. 2002), yellow fever virus in the Western Region of Saudi Arabia and Sindbis virus in the Eastern Region of Saudi Arabia (Will, et al. 1985) respectively. Since this study revealed the incidence of these three species in the Al Baha Region, considerable efforts should be made to manage these mosquito species in order to minimize these epidemic human diseases in this region.

Culiseta longiareolata occurred in the study area in small numbers. Adults of this species never enter houses and rarely bite human (Salit, et al. 1994), so this species appears to be of no medical importance. However, its larvae may be cannibalistic and prey on aquatic insects

and tadpoles (Blaustein and Margalit, 1994).

Results of this study also indicated that adult mosquitoes are active throughout the year, but at different magnitude, presumably as a result of the favorable climate during sustaining the development and survival of mosquitoes and in its turn complicating their management. Furthermore, agricultural expansion, establishment of new irrigation canals, pools and dams, as well as extensive farming, could all contribute to the spread of mosquitoes in the Al Baha Region (Al Zahrani, 2007).

In general, the number of adult and larvae mosquitoes of different species surveyed in this investigation was quite very low, most likely due to regular and extensive adulticides and larvicides application to control malaria disease in the region.

An. stephensi, *An. subpictus* and *An. turkhudi* were collected as larvae, but not as adults, indicating that CDC and NJ light traps used in this study may not be attractive to adult *Anopheles*. Therefore, the use of more efficient traps for sampling *Anopheles* such as the spray sheet method, is recommended.

The diversity of mosquitoes in this region evokes fear of potential health problems. Further studies on ecology, biology and vectorial capacity in disease transmission are needed before initiating control programs.

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REFERENCES

- Abdoo, AMMO, and Alshahrani, AM (2003) Prevalence and distribution of Anopheline mosquitoes in malaria endemic areas of Asir Region, Saudi Arabia. *Eastern Mediterranean Health Journal* **9** (3): 240-247.
- Abdullah, MA, and Merdan, AI (1995)

- Distribution and ecology of the mosquito fauna in the southwestern Saudi Arabia. *J. Egypt. Soc. Parasitol* **25** (3): 815-837.
- Alahmed, AM, Al Khereji, MA and Kheir, SM** (2007) Distribution and habitat of mosquito larvae (Diptera: Culicidae) in Riyadh Region, Saudi Arabia. *Journal of King Saud University (Agricultural Sciences)* **9** (2): 39-55.
- Al Ghamdi, K, Masroor, Alikhan, Jazem Mahyoub and Afifi, ZH** (2008) Studies on identification and population dynamics of Anopheline mosquito from Jeddah Province, Saudi Arabia. *Bioscience Biotechnology Research Communication* **1**: 19-24.
- Al Khereji, AM, Alahmed, AM, and Kheir, SM** (2007) Survey and seasonal activity of adult mosquitoes (Diptera: Culicidae) in Riyadh City. In: *Saudi Arabia. Research Bull. No. (152)*, Food Sci. & Agric. Res. Centre, King Saud University. pp 5-17.
- Al Tubiakh, SS** (1995) *Bionomics of Mosquito in Kuwait*. M. Sc. thesis of Public Health Science (Vector control), High Institute of Public Health, University of Alexandria, Alexandria, Egypt, pp. 219.
- Al Zahrani, MH** (2007) *Impact of Irrigation Systems on Malaria and Rift Valley Fever Transmission in Jazan, Saudi Arabia*. Ph. D. thesis, University of Liverpool, Liverpool, U.K.
- Blaustein, L and Margalit, J** (1994) Mosquito larvae *Culiseta longiareolata* (Diptera: Culicidae) prey upon and compete with tadpole (*Bufo viridis*). *J. Animal Ecology* **63** (4): 841-850.
- Buttiker, W** (1981) Observation on urban mosquitoes in Saudi Arabia. *Fauna of Saudi Arabia* **3**: 472- 479.
- Glick, JI** (1992) Illustrated key to the female *Anopheles* (Diptera: Culicidae) of Southwestern Asia and Egypt. *Mosq. Syst.* **24**(2): 125-153.
- Harbach, RE** (1988) The mosquitoes of the subgenus *Culex* (Diptera: Culicidae) in Southwestern Asia and Egypt. *Contribution of the American Entomological Institutet* **24** (1): 1- 246.
- Hopkins, GH** (1952) *Mosquitoes of the Ethiopian Region, 1- Larval Bionomics of Mosquitoes and Taxonomy of Culicinae Larvae*. Printed by Order of the Trustees, London, pp. 355.
- Jupp, PG, Kemp, A, Grobbelaar, A, Leman, P, Burt, FJ, Alahmed, AM, Almujailli, D, Alkhamees, M, and Swanepoel, R** (2002) The 2000 epidemic of Rift Valley fever in Saudi Arabia: mosquito vector studies. *Med. and Vet. Ent.* **16**: 245-252.
- Mattingly, PF, and Knight, KL** (1956) The mosquito of Arabia, *Bull. of the British Museum (Natural History)*, Ent. **4** (3): 89-141.
- Miller, BR, Godsey, MS, Crabtree, MB, Savage, HM, Al-Mazrao, Y, Al-Jeffri, MH, Abdoon, AM, Al-Seghayer, SM, Al-Shahrani, AM, and Ksiazek, TG** (2002) Isolation and genetic characterization of Rift Valley fever virus from *Aedes vexans arabiensis*, Kingdom of Saudi Arabia. *Emerging Infectious Diseases* **8** (12): 1492-1494.
- Salit, AM, Zakaria, M, Balba, M and Zaghloul, T** (1994) The mosquito fauna of Kuwait. *Journal of University of Kuwait (Science)* **21**: 77-84.
- SAS system for windows**, 2001. SAS Institute, Inc., Cary, NC., USA.
- Wills, WM, Jacob, WL, Franczy, DB, Oertley, RE, Anani, E, Callsher, CH and Monath, TP** (1985) Sindbis virus isolation from Saudi Arabian mosquitoes. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **79**(1): 63-66.
- Zaher, AR** (1973) *Review of Ecology of Malaria vectors in the Eastern Mediterranean Region*. WHO report, Geneva, pp.21.

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