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Seasonal Abundance of the Common Mosquitoes: *Culex pipiens, Cx. quinquefasciatus* and *Cx. sitiens* (Diptera: Culicidae) in the Western Coast of Saudi Arabia

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ABSTRACT

The seasonal abundance of the common larval and adult species: *Culex pipiens, Cx. quinquefasciatus* and *Cx. sitiens* was examined in four sea ports (Jeddah, Yanbu, Duba and Haql) and two cities (Taif and Mecca) representing the three regions of the western part of the Kingdom (Mecca, Al Madinah and Tabouk) based on larval density (number per a survey unit, SU each of 10 dips) and adult density (number per a trap). Larvae were collected by dipping and adults by CDC, Black Hole and UV light traps biweekly from January 2013 to December 2014. The compiled density of the two years for each species in the different localities and in all localities altogether was calculated. *Cx .pipiens* larvae breed all year round with peaks of abundance were during autumn in Taif (78.02 larva / SU), summer in Jeddah (38.59 larva / SU), spring in Tabouk (10.61 larva / SU) and autumn for all areas altogether (21.63 larva / SU). *Cx. quinquefasciatus* larvae breed all year round with peaks of abundance were during winter in Jeddah and Yanbu (128.92 and 36.04 larva / SU in the two localities, respectively) and for all areas altogether (34.54 larva / SU). *Cx. sitiens* larvae breed all year round in Jeddah, with peak of abundance was in summer (77.67 larva / SU). *Cx. pipiens* adults were active all year round with peaks of abundance during autumn in Taif , Mecca and Yanbu (4.68, 4.97 and 3.96 adult / trap, respectively) and spring in Tabouk, and all areas together (9.50 and 5.36 adult / trap, respectively). *Cx. quinquefasciatus* adults were active all year round with peaks of abundance in spring in all localities either separately (Taif: 11.07, Jeddah: 31.22, Yanbu: 1.93 and Tabouk: 7.78 adult / trap) except Mecca with peak during autumn (11.31 adult / trap) or in all areas altogether (11.06 adult / trap). The obtained results are of importance in predicting the period of maximum risk of bancroftian filariasis, *Wuchereria bancrofti* and West Nile Virus transmission and for carrying out an effective control program.

INTRODUCTION

The Kingdom of Saudi Arabia (16° and 33° N, 34° and 56° E) occupies about 80% of the Arabian Peninsula with an area of 2,149,690 km^2 and a population of 30,770,375 (2014 estimate). Saudi Arabia's geography is dominated by the Arabian Desert and associated semi-desert (Wikipedia: *http: //en.wikipedia.org/ wiki/KSA*). The Western part (the Hijaz) of the Kingdom includes the west coast, north of Asir. It contains a mountain chain

(with peaks rising to 3,000 meters, running south to north and decreasing gradually in elevation as it moves northward) and the coastal plain bordering the Red Sea. It also includes the city of Jeddah which is the main port for thousands of pilgrims arrive annually as the first step on their trip to Holy Cities of Mecca (to the east) and Al Madinah (to the north). In the mountains above Mecca and Jeddah is the town of Taif. Its elevation gives it a climate far cooler and pleasanter than either Jeddah or Mecca and without the uncomfortable humidity of such two cities. The coastal area of the Western Region is notorious for its humidity, with summer temperatures rising to above 40^{o}C.

Mosquitoes of Saudi Arabia were surveyed by several workers (Mattingly and Knight, 1956; Buttiker, 1981; Wills *et al*., 1985; Abdullah and Merdan, 1995; Jupp *et al*., 2002; Miller *et al*., 2002; Abdoon and Alshahrani, 2003; Abdoon, 2004; Alahmed *et al*., 2007; 2010; Alahmed, 2012; Al Ashry *et al*., 2014; Bakr *et al*., 2014). Such surveys resulted in the occurrence of fifty three species belonging to 11 genera: *Anopheles, Culex*, *Lutzia, Ochlerotatus*, *Stegomyia, Aedes, Aedimorphus, Fredwardsius, Culiseta, Uranotaenia* and *Orthopodomyia.* In addition, several surveys were conducted in the western part of the Kingdom (AI Ali *et al*., 2008; Al Ghamdi *et al*., 2008; Alahmed *et al*., 2009; Kheir *et al*., 2010; Al Ahmad *et al*., 2011; Khater *et al.* , 2013; Alikhan *et al*., 2014; Mahyoub *et al*., 2015) and identified 33 species of 9 genera: *Culex* (12 spp.), *Anopheles* (14 spp.), *Ochlerotatus* (2 spp.) and one species each of *Lutzia* , *Stegomyia, Aedes*, *Culiseta* and *Uranotaenia.*

The Saudi Arabian mosquitoes mainly: *Anopheles arabiensis, An. stephensi, An. sergenti, An. fluviatilis, An. multicolor, Culex pipiens, Cx. quinquefasciatus, Cx. tritaeniorhynchus, Cx. perexiguus, Stegomyia aegypti* and *Aedimorphus v. arabiensis* are important as vectors of several diseases. The most common mosquito-borne diseases include filariasis, RVF, dengue fever and malaria (Sebai *et al*., 1974; Warrel, 1993; Omar, 1996; Al-Seghayer *et al.*, 1999; Fakeeh and Zaki, 2001; 2003; Haleem *et al*., 2002; Jupp *et al*., 2002; Miller *et al*., 2002; Abdoon and Alshahrani, 2003; Al-Hazmi *et al*., 2003; Balkhy and Memish, 2003; Madani *et al*., 2003; Flick and Bouloy, 2005; Al-Tawfiq, 2006; Ayyub *et al.*, 2006; Elfadil *et al*., 2006; Khan *et al*., 2008; El-Gilany *et al*., 2010; Al-Qabati and Al-Afaleq, 2010;Aziz *et al*., 2014).

In a recent survey of mosquito fauna in the western part of the kingdom (Hassan *et al*., in prep.), 19 species were identified of which *Cx. pipiens* and *Cx. quinquefasciatus* were the most common species as larvae (22.24 and 47.11% of 10930 for the 2 species, respectively) and adults (27.42 and 57.52% of 33108 for the 2 species, respectively). In addition to *Cx sitiens* which was also common as larvae (11.89%). The two former species are important as the chief vectors of bancroftian filariasis, *Wuchereria bancrofti* in many parts of the world including the Middle East and Eastern Mediterranean countries (AI-Ali *et al*., 2008). The disease has been reported from Abha in the southwest of the Kingdom (Omar, 1996) and Riyadh (Haleem *et al*., 2002). Moreover, Omar (1996) reported that the local *Cx. pipiens* may act as a potential vector of introduced bancroftian filariasis to Saudi Arabia. In addition, *Cx. pipiens* was found to harbor West Nile Virus (WNV) in the examined mosquitoes from Al Madinah (Al-Ali *et al*., 2008).

The knowledge of the seasonal activity of mosquitoes is of importance in predicting the period of maximum risk of disease transmission and for carrying out an effective control program. However, the seasonal abundance of mosquitoes was studied only twice in Makkah by Alahmed *et al.* (2009) and Mahyoub *et al.* (2015). In some other parts of the Kingdom, several workers examined the seasonal abundance of the prevailing mosquito species: Riyadh (Al Ahmed and Al Kheriji, 2005; El-Khereji *et*

al., 2007), AL Ahsaa (Ahmed *et al.,* 2011), Asir (Al Ashry *et al.,* 2014) and Jizan (Nassar *et al.,* 2016). Due the abundance of *Cx. pipiens, Cx. quinquefasciatus* and *Cx sitiens* and medical importance of the two former species, this study was planned to examine their seasonal abundance in order to predict the risk period of disease transmission.

MATERIALS AND METHODS

The Study Area and Period

The study was carried out in four sea ports (Jeddah: 21°32′36″N, 39°10′22″E; Yanbu: 24°05′N, 38°00′E; Duba: 27°20′57.3″N, 35°41′46.2″E and Haql: 29°17′N, 34°56′E) and 2 cities (Taif: 21°26′N, 40°21′E and Mecca: 21°30′N, 41°0′E) representing the 3 Regions of the western part of the Kingdom namely Mecca (Makkah) "21°25′N, 39°49′E", Al Madinah (Al-Madīnah El-Munawarah) "25°0′N, 39°30E" located along the Red Sea coast and Tabouk (Tabuk) "28°0′N, 37°0′E" located along the north-west coast of the country, facing Egypt across the Red Sea. (Fig. 1). In each locality, certain sites were selected for sampling mosquitoes. Each site was biweekly surveyed during the period from January 2013 to December 2014.

Fig. 1: surveyed localities in the western part of Saudi Arabia

Sampling and Processing of Mosquito Larvae and Adults

In each site, the larvae were sampled in the water bodies by using a plastic dipper, 125 mm in diameter with a 90 cm aluminum telescopic handle. Three samples of 10 dips (a survey unit, SU) per breeding site were taken. Collected larvae were placed in labeled plastic bags (Nasco whirl pack 4002 filline U.S.A) and transported to the laboratory in a picnic ice box containing cold water to prevent overheating. At the laboratory, 3rd and 4th larval instars were killed with hot water and preserved in labeled specimen tubes containing 70% ethyl alcohol to be ready for identification. Adults were collected using three types of traps: (1) the CDC (Center for Disease Control) miniature light trap (Model 512, John W. Hock Co., Gainesville, FL, USA), (2) V-Mart Super photo-catalyst "Black Hole (BH) trap" (Venus Technology Co., Ltd. Wangthonglang, Bangkok, Thailand) and (3) UV (Ultra violet) trap (John W. Hock Company, Gainesville, Florida, U.S.A). The traps were set before sunset and collected after sunrise next morning. The collected mosquitoes were aspirated, placed in labeled paper cups that kept in a picnic ice box while being transported to the laboratory. Mosquitoes were preserved in 70% alcohol till identification to the species level. At the laboratory, collected larvae and adults were identified according to keys of Mattingly and Knight (1956) and Al Ahmad *et al.* (2011).

Data Analysis

The seasonal mean density of larvae (number collected per a SU) and adults (number collected per a trap) of each species in each of the study locality were calculated. The compiled density of each species in all

localities during the two years altogether was also calculated.

RESULTS

The seasonal abundance of the three common larval species (*Cx. pipiens, Cx. quinquefasciatus* and *Cx. sitiens*) and the two adult species (*Cx. pipiens* and *Cx. quinquefasciatus*) was examined in the different localities of species occurrence based on larval density (number collected per a SU) and adult density (number collected per a trap). The compiled density of each species in the two years and in all localities was calculated. The results indicated that:

Cx. pipiens Larvae

Only larvae were collected during winter 2013 in Mecca (1 larva: 0.08 / SU) and 2014 in Yanbu (25 larva: 4.17 / SU). Peaks of abundance were during autumn 2013 and 2014 in Taif and all localities altogether, during summer 2013 and 2014 in Jeddah and during spring 2013 and 2014 in Tabouk (Table 1). For the two years together (Fig. 2), the species was reported breeding all year round with peaks of abundance during autumn in Taif (78.02 larva / SU), summer in Jeddah (38.59 larva / SU) and spring in Tabouk (10.61 larva / SU). High breeding was also observed during winter in Taif (8.37 larva / SU), autumn in Jeddah (30.00 larva / SU) and winter in Tabouk (3.83 larva / SU). In general, for all localities altogether mean densities indicate autumn peak (21.63 larva/SU) with high breeding was also observed in summer (8.12 larva / SU).

Table 1: Seasonal abundance of mosquito larvae (No / Survey Unit)

Species	Locality	2013				2014			
		Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Cx . pipiens	Taif	8.57	0.00	0.00	143.33	8.17	4.27	1.30	12.70
	Mecca	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Jeddah	5.00	0.00	41.00	30.83	5.00	7.17	36.17	29.17
	Yanbu	0.00	0.00	0.00	0.00	4.17	0.00	0.00	0.00
	Tabouk	2.15	3.92	1.83	0.00	5.50	17.29	0.86	0.22
	All	3.16	0.78	8.57	34.83	4.57	5.75	7.67	8.42
Cx. quinquefasciatus	Taif	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00
	Mecca	2.31	6.58	0.00	0.00	10.63	8.86	0.00	0.00
	Jeddah	123.83	102.83	110.83	0.00	134.00	50.67	36.67	79.17
	Yanbu	43.25	33.00	2.50	42.00	28.83	14.00	4.67	20.83
	Tabouk	0.00	0.00	0.00	0.00	2.25	3.86	0.00	2.22
	All	33.88	28.48	22.67	8.40	35.19	15.48	8.27	20.44
Cx. sitiens	Jeddah	11.67	48.50	87.00	8.33	0.00	11.83	68.33	13.33
	Yanbu	48.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	All	30.27	24.25	43.50	4.17	0.00	5.92	34.17	6.67

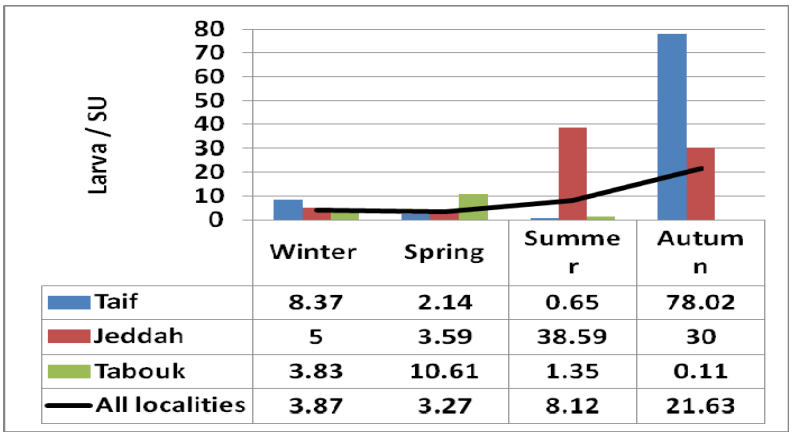


Fig. 2: Seasonal abundance of *Cx .pipiens* larvae (2013+2014)

***Cx. quinquefasciatus* Larvae**

The species was reported in all localities. Only larvae were collected during winter 2014 in Taif (3 larvae: 0.25 / SU), winter 2013 and 2014 (2.31 and 10.63 / SU, respectively) and spring 2013 and 2014 (6.58 and 8.86 / SU, respectively) in Mecca while in Tabouk larvae were reported only in 2014 with no prominent peak (winter: 2.25, spring: 3.86, autumn: 2.22 larva / SU). Peaks of abundance were observed during winter 2013 and 2014 in Jeddah, Yanbu and in all localities (Table 1). For the two years altogether in Jeddah and Yanbu (Fig. 3), the species was reported breeding all year round with peaks of abundance were during winter (128.92 and 36.04 larva / SU in the 2 localities, respectively). High breeding was also observed in spring (76.75 larva / SU) and summer (73.75 larva / SU) in Jeddah and in autumn in Yanbu (31.42 larva / SU). In general, mean densities for all localities indicate peak of abundance was during winter (34.54 larva / SU). High breeding was also observed in spring (21.98 larva / SU).

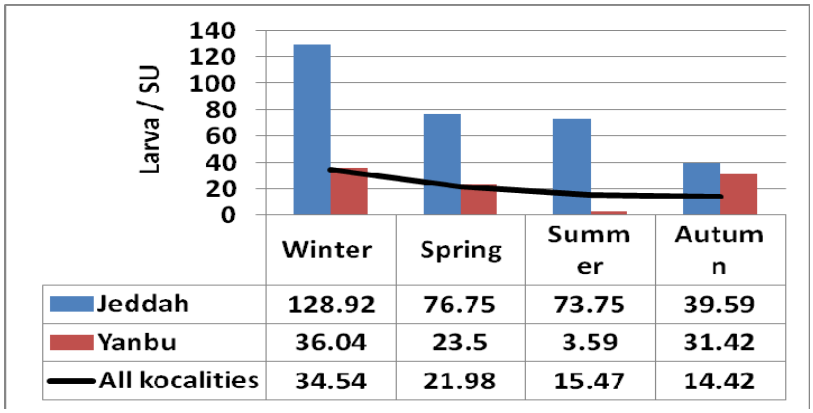


Fig. 3: Seasonal abundance of *Cx. quinquefasciatus* larvae (2013+2014)

***Cx. sitiens* Larvae**

The species was reported in Jeddah and Yanbu. In Yanbu, only 195 larvae (48.86 larva / SU) were collected during winter 2013. In Jeddah, the species breeds all year round with peaks of abundance were during summer 2013 (87.00 larva / SU) and 2014 (68.33 larva / SU). High breeding was also observed in spring 2013 (48.50 larva / SU) and autumn 2014 (13.33 larva / SU) (Table 1). For the two years altogether (Fig. 4) in Jeddah, the species peaked in summer (77.67 larva / SU) with high abundance also in spring (30.17 larva / SU).

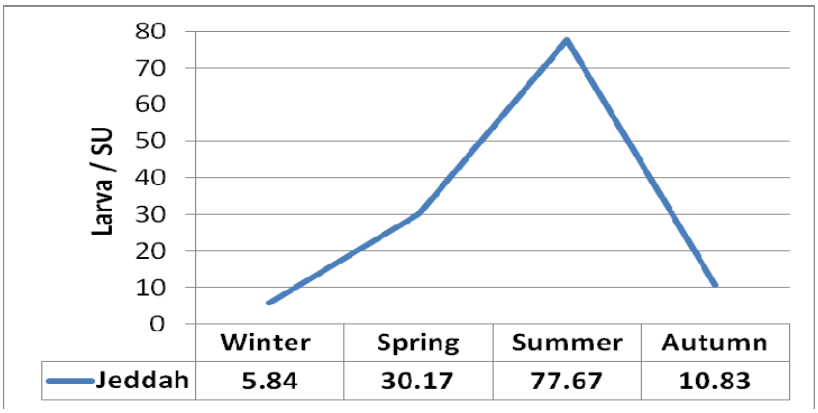


Fig. 4: Seasonal abundance of *Cx. sitiens* larvae (2013+2014)

Cx. pipiens Adults

The adults were reported in all localities except Jeddah and were active all year round. Peaks of abundance were observed during winter 2013 and spring 2014 in Taif and all localities altogether, winter 2013 and autumn 2014 in Mecca and spring 2013 and 2014 in Yanbu and Tabouk (Table 2). For the two years together (Fig. 5), in Taif, Mecca and Yanbu, peaks of abundance were during autumn (4.68, 4.97 and 3.96 adult / trap, respectively). The high activity was during winter (3.64, 4.21 and 3.82 adult / trap, respectively). In Tabouk and all areas, peaks of abundance were during spring (9.5 and 5.36 adult / trap, respectively). High activity was during autumn (6.5 and 4.45 adult / trap, respectively) and winter (4.65 and 4.08 adult / trap, respectively).

Table 2: Seasonal abundance of mosquito adults (No / trap)

Species	Locality	2013				2014			
		Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Cx . pipiens	Taif	5.89	2.88	1.14	3.43	1.38	2.28	0.74	1.25
	Mecca	6.76	4.97	0.31	1.27	1.65	0.71	1.77	8.67
	Jeddah	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Yanbu	3.90	6.15	2.02	4.12	3.73	6.85	0.87	3.80
	Tabouk	6.38	6.47	1.68	5.97	2.92	12.52	5.55	7.02
	All	5.73	5.12	1.29	3.70	2.42	5.59	2.23	5.19
Cx. quinquefasciatus	Taif	2.98	11.85	5.86	8.83	2.98	10.29	4.86	6.68
	Mecca	5.20	3.52	1.34	13.41	4.76	3.05	1.54	9.20
	Jeddah	38.30	38.30	8.82	9.18	11.75	24.13	6.88	7.32
	Yanbu	0.22	1.90	0.00	1.05	2.65	1.95	0.00	0.88
	Tabouk	4.68	8.63	1.22	4.03	7.92	6.93	5.33	8.83
	All	10.28	12.84	3.45	7.30	6.01	9.27	3.72	6.58

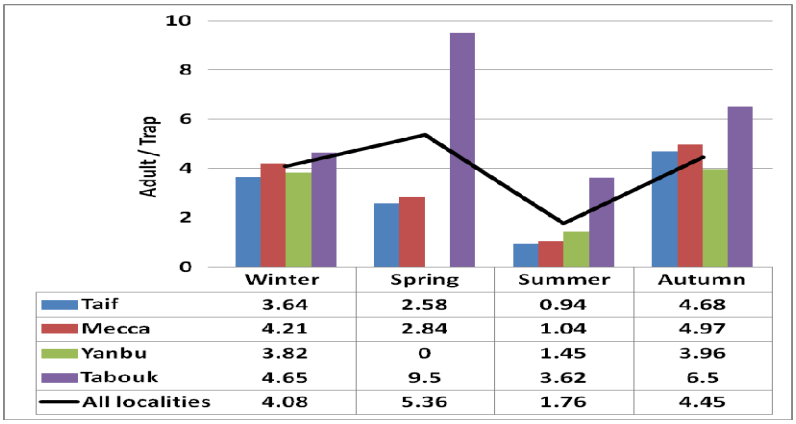
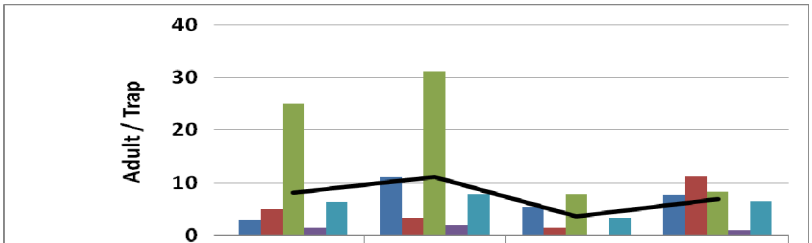


Fig. 5: Seasonal abundance of *Cx. pipiens* adults (2013+2014)

Cx. quinquefasciatus Adults

The adults were active all year round with peaks of abundance were during spring 2013 and 2014 in Taif and all localities altogether, autumn 2013 and 2014 in Mecca, winter/spring 2013 and spring 2014 in Jeddah, spring 2013 and winter 2014 in Yanbu and spring 2013 and autumn 2014 in Tabouk (Table 2). For the two years together (Fig. 6), peaks of abundance were during spring in all localities (Taif: 11.07, Jeddah: 31.22, Yanbu: 1.93 and Tabouk: 7.78 adult / trap) except Mecca with a peak during autumn (11.31 adult / trap). High activities were during autumn (Taif : 7.76 adult / trap), winter (Mecca :4.98, Jeddah: 25.03 and Yanbu: 1.44 adult / trap), and autumn (Tabouk: 6.43 adult / trap). In all localities altogether, peak of abundance was

during spring (11.06 adult / trap), High activity was during winter (8.15 adult / trap).



	Winter	Spring	Summer	Autumn
Taif	2.98	11.07	5.36	7.76
Mecca	4.98	3.29	1.44	11.31
Jeddah	25.03	31.22	7.85	8.25
Yanbu	1.44	1.93	0	0.97
Tabouk	6.3	7.78	3.28	6.43
All localieies	8.15	11.06	3.59	6.94

Fig. 6: Seasonal abundance of Cx. *quinquefasciatus* adults (2013+2014)

DISCUSSION

The knowledge of the seasonal activity of mosquitoes is of importance in predicting the period of maximum risk of disease transmission and for carrying out an effective control program. For this, the seasonal abundance of *Cx. pipiens, Cx. quinquefasciatus* and *Cx. sitiens*, the common and important disease vector species was examined in the different localities of species occurrence. As each of these species had a somewhat similar trend during the two years of study, so that the discussion will be focused on the compiled results of the two year together.

Cx. pipiens larvae were reported in all areas of the study breeding all year round in most areas (Taif, Jeddah and Tabouk) with autumn peak and high breeding in summer, i.e. during seasons with high temperature. Similarly, regression analysis (Hassan *et al.*, in perp.) indicates that density was directly related to temperature i.e., increases as temperature increases (b = 1.96, P>0.05). *Cx. quinquefasciatus* larvae were reported in all localities breeding all year round only in Jeddah and Yanbu with peaks of abundance were during winter. High breeding was also observed in spring, i.e. during the seasons with lower temperature. However, regression analysis (Hassan *et al.*, in perp.) indicates that density was directly related to temperature (b = 2.64, P<0.05). *Cx. sitiens* in Jeddah breeds all year round and peaked in summer with high abundance also in spring, i.e. mostly abundant in high temperature. Such finding is supported by regression analysis (Hassan *et al.*, in perp.) which indicates that density was directly related to temperature (b = 6.15, P>0.05).

Culex pipiens and *Cx. quinquefasciatus* adults were collected in all localities (except Jeddah for *Cx. pipiens*) and were active all year round with general peaks of abundance during spring, i.e. during the mild daily mean temperature (25.90: 19.93-31.87°C) and RH (48: 36-60%). Higher activity was during autumn (27.75: 23.63-31.87°C, 50: 33-67% RH) for *Cx. pipiens* and winter (20.75: 16.43-25.07°C, 58: 53-63% RH) for the two species than during summer with high mean temperature (32.5: 29.1-35.9°C) and lower RH (42: 25-59%). In a concurrent study (Hassan *et al.*, in prep,), multiple regression analysis revealed that densities of *Cx. pipiens* and *Cx. quinquefasciatus* decrease as temperature increases (b = -0.06 and -0.01 for the 2 species. respectively, P > 0.05) and increase as RH (b = 0.05, P > 0.05 for the two species, respectively) increases.

There is only two previous studies dealing with seasonal abundance of *Cx. pipiens* and *Cx. quinquefasciatus* adults together with some other mosquito species in Makkah Region. Alahmed *et al.* (2009) collected mosquitoes throughout the year and observed two peaks in June and December

when temperature was 31 and 35°C, respectively. Mahyoub *et al.* (2015) pointed out that *Culex* genus fluctuated throughout the year and was found to make 3 or 4 peaks.

In some other parts of the Kingdom, several workers examined the seasonal abundance of the prevailing mosquito species. Al Ahmed and Al Kheriji (2005) collected *Culex quinquefasciatus* adults and three other species in Ar Riyadh City. The authors found that the high numbers were collected during December and April when temperature and humidity were optimum, while during summer and winter numbers were low. El-Khereji *et al.* (2007) studied the seasonal activity of adult mosquitoes in Riyadh City and showed that the adult mosquitoes were present throughout the year with tow peaks for the seasonal activity: in December-January and April-May where temperature and humidity were optimum. Ahmed *et al.* (2011) reported that mosquitoes in AL Ahsaa are prevalent in both winter and spring seasons, rarely encountered in summer and are found in moderation during the autumn months. Al Ashry *et al.* (2014) reported that mosquitoes in Asir were found breeding all year round with peaks of abundance during spring for *Culex* spp., i.e. during mild months. Two peaks of mosquito activity were attained yearly in Jizan: February to April and July to September after a rainy season which leads to more breeding sites (Nassar *et al*., 2016).

CONCLUTION

The abundance and seasonality of the studied mosquito species mainly *Cx. pipiens,* and *Cx. quinquefasciatus* with their medical importance pause a threat of disease transmission in this important part of the Kingdom of being containing the wholly places which are visited all year round by millions of people for hag and omra. The results may be of help in planning an effective control program.

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ARABIC SUMMERY

الوفرة الموسمية للبعوض الشائع: كيولكس بيبانز، كيولكس كوينكيفاسكياتس و كيولكس سيتنز (ذوات الجناحين : البعوضيات) في الساحل الغربي من السعودية

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تم دراسة الوفرة الموسميه ليرقات والبعوض اليافع للأنواع الشائعة: كيولكس ببانز، كيولكس كوينكيفاسكياتس و كيولكس سيتنز في أربعة موانئ (جدة، ينبع، ضباء وحقل) ومدينتين (الطائف ومكة) الذين يمثلون المناطق الثلاث في الجزء الغربي من المملكة (مكة المكرمة والمدينة المنورة وتبوك) امدة عامين من يناير ٢٠١٣ إلى ديسمبر ٢٠١٤. عموما، تتواجد يرقات كيولكس ببانز طوال العام مع ذروة الوفرة خلال فصل الخريف، تتواجد يرقات كيولكس كوينكيفاسكياتس طوال العام مع ذروة الوفرة خلال فصل الشتاء و تتواجد يرقات كيولكس سيتنز طوال العام في جدة، مع ذروة الوفرة في الصيف. ينشط الطورااليافع لبعوضة كيولكس ببانز على مدار السنة مع ذروة النشاط خلال فصل الخريف كما وان الطورااليافع لبعوضة كيولكس كوينكيفاسكياتس ينشط على مدار السنة مع ذروة النشاط في الربيع . وتعتبرالنتائج التي تم الحصول ذو أهمية في التنبؤ بفترة اختطار نقل داء الفلاريا اللمفاوية وفيروس غرب النيل ولتنفيذ برنامج فعال للمكافحة.