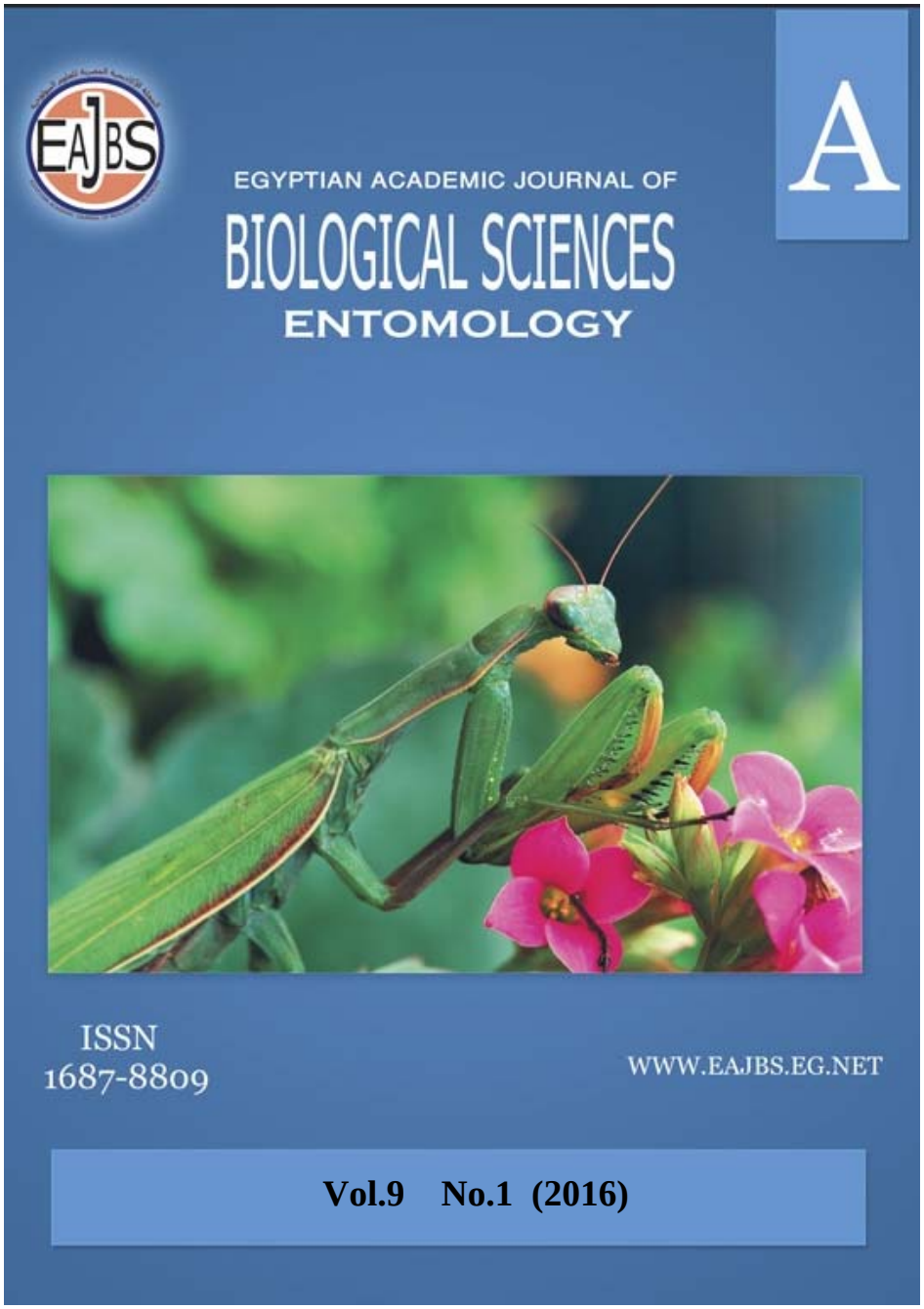

Egyptian Academic Journal of Biological Sciences is the official English language journal of the Egyptian Society for Biological Sciences, Department of Entomology, Faculty of Sciences Ain Shams University.

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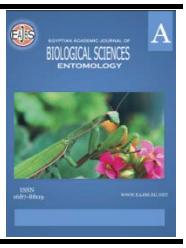
Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol.9 (1)pp.1-13 (2016)*

Egypt. Acad. J. Biolog. Sci., 9(1): 1-13 (2016)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
www.eajbs.eg.net



Seasonal Abundance of Mosquitoes in Jizan Province

Mamdouh I. Nassar[1], Reda F. A. Bakr[2&4], Mohammed S. Abdeldayem[5,6], Nehad M. El-Barky[3] and Thorayia F. Kotb[2]

1-Department of Entomology, Faculty of Science, Cairo University, Cairo, Egypt
2-Department of Entomology, Faculty of Science, Ain Shams University, Cairo, Egypt
3-Department of Entomology, Faculty of Science, Benha University, Al Qalyubia, Egypt
4-Department of Biology, Faculty of Science and arts, Baisha University, Baisha, KSA
5-Department of Biology, Faculty of Science, Jazan University, Jazan, KSA
6-Virology Sector, VACSERA-Egypt
E.Mail : redabakr55@gmail.com

ARTICLE INFO

Article History
Received:25/12/2015
Accepted: 15/1/2016

Keywords:
Mosquitoes,seasonal abundance, Jizan

ABSTRACT

Effect of climatic factors on mosquitoes abundance in Jizan province was studied through this research reporting that rainfall rate was the most effective and significant factor ($P<0.01$, $r= 0.459$), as well as, the presence of two peaks of mosquito activity which were attained yearly (February–April and July–September) after a rainy season in the frequently visited sites. On the other hand, mosquito activity was increased in occasionally visited sites in winter rather than that of summer season.

INTRODUCTION

Mosquitoes are Dipterous insects (true flies), suborder Nematocera in the family of Culicidae. There are three subfamilies; Anophelinae, Culicinae, and Toxorhynchitinae. Anophelinae and Culicinae contain mosquitoes that have medical importance which are able to transmit diseases pathogens (Knight and Stone, 1977). Culicidae contain around 3,500 species, which have been grouped into 42 genera and 135 subgenera (Knight and Stone, 1977; Crans, 2004; Rueda, 2008). Seventy six people have died from an outbreak of Rift Valley fever and 408 people had contracted the disease (Ahmad, 2000). Three filarial cases were reported from Saudi residences in Armed Forces Hospital, Riyadh in 2002 (Haleem *et al.*, 2002).

Ecology, development, behavior, survival of mosquitoes, and the transmission dynamics of the diseases are strongly influenced by climatic factors. Temperature, rainfall, and humidity are especially important, but others, such as wind and the duration of daylight, can also be significant (Cook, 1996). Some authors have assured that the availability of larval habitats (Hayes and Charlwood, 1979; Guimarães *et al.*, 2000) and the abundance of mosquitoes are mainly controlled by rainfall (Guimarães *et al.*, 2001), even in artificially altered environments (Forattini*et al.*, 1996) like Peixe Angical hydroelectric scheme (Tocantins, Brazil) PAHS. In the dry Savanna of Africa, vector species can have seasonal fluctuations in abundance, declining to low levels in dry seasons (Charlwood *et al.*, 1995; Lemasson *et al.*, 1997).

The shortage of rainfall rateas well as the widespread use of insecticides were the most important causes of the limitations to collect mosquitoes in most locations of Jizan province, at the same time mosquito breeding sites located in the border areas were sustained by perennial flow from the Yemen mountain streams (Al-Sheik, 2011). Mosquito genera in Asir province breed year round with peaks of abundance during spring for *Anopheles* spp. and *Culex* spp., and during winter for Aedine spp. and *Cs. longiareolata* (Al-Ashry *et al.*, 2014). For the past few decades, Saudi Arabia has witnessed big efforts in social development and urbanization, which have affected insect fauna, particularly the mosquitoes. Expansion of agricultural projects and development of water resources, in addition to the favourable climatic conditions for mosquito survival and developments in some parts of the Jizan province, have led to the creation of more permanent and temporary breeding sites for mosquitoes. No detailed information is available on the mosquito fauna of the Jizan province. Study the effects of some climatic factors on the seasonal abundance of mosquitoes in the study area became a necessary.

MATERIALS AND METHODS

The Study Area

Jizan province lies in the southwest of KSA (N17.31 E42.71). It occupies an area of 13,000 km^2. It includes 455 villages. The topography of the area varies and consists of: (a) Sarawat Mountain ranges to the east with elevation up to 2500 m above sea level (A. S. L.), (b) Hilly middle sector with elevation ranges 300-600 m A. S. L., and(c) Western coastal sector with elevation up to 30 m A. S. L. The climate is subtropical; with annual temperature 30°C relative humidity (RH) is relatively high and usually between 50 and 70%, sometimes reaching 90%,annual precipitation165 mm in the coastal sector, while in the Sarawat mountain ranges it ranges 300-500 mm and rainfall rate (RR) occurs throughout they earin the mountain zone. The rainy seasonis between August and October with amonthly average of 77&56.7mm, respectively, though occasional monsoonrainscanoccur during April-May. The wadisin Jizan, especially on the border with Yemen, do not depend only on precipitation in the region, but also receive an almost continuous influx of water from Yemen viathe mountains. (datafrom ministry of Agriculture, Jazan, 1981-2008).Coordinates were recorded using GPS (Garmin, USA) for each collection site. Jizan province was divided into: Frequently visited collection sites which were visited twice per month from February 2009 to September 2010. Those sites were Gizan, Arda, Baish, and Ahad El Masarha (Fig. 1).

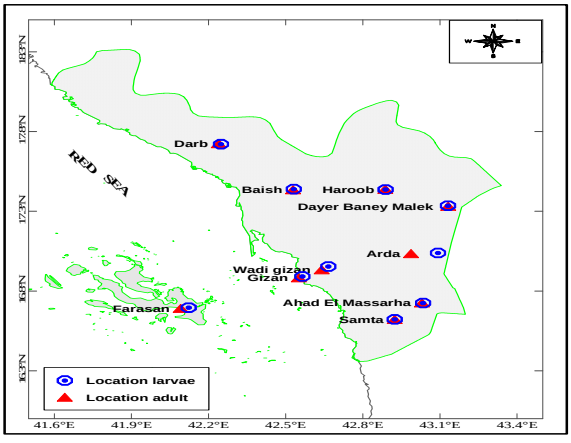


Fig. 1: Map of Jazan region showing collection sites of Mosquitoes larvae and adults.

Occasionally visited sites which were visited twice per season of summer and winter. Those were Haroob, Wadi Gizan, Samta, El-Darb, Dayer Bany Malek, and Farasan (Fig. 1).

Larval Collection

A standard mosquito larval dipper with extendable handle was used to collect larval specimens. Almost three to five scoops were taken from each breeding site (350 ml each). Larvae were preserved in 80% ethyl alcohol in glass vials and labeled for transfer to the laboratory. In the laboratory, 4th instar larvae have been identified using identification keys based on morphology (Mattingly and Knight, 1956; Harbach, 1988; Al Ahmad *et al.*, 2011).

Adult Collection

Adult mosquitoes were collected using CDC light traps (Bioquip Company, Gardena, CA 90248-3602, USA). Each CDC light trap was operated once monthly and operated from sunset to sunrise of the following day throughout the study period. The collected mosquitoes were packed, labeled, and transported to the Laboratory. Adult mosquitoes were counted and identified using identification keys of Mattingly and Knight (1956), Harbach (1988), and Glick (1992).

Climatic Factors

Climatic factors, temperature(Temp.), relative humidity(RH), rainfall(RR) rate, and wind speed(WS), were taken from the metrological stations of the Ministry of Agriculture that distributed in different parts of JI.

Statistical Analysis

Data were statistically analyzed using SPSS Program, version 12. Linear regression correlation coefficient was used to study the effects of relative humidity, temperature, rain fall rate, and wind speed on the distribution of different mosquito larvae and adults.

RESULTS AND DISCUSSION

The effect of climatic factors on mosquitoes abundance was studied through our research showing that RH, WS, and Temp. have insignificant effect ($P>0.05$) on abundance of mosquitoes. RR was the most effective, significant factor ($P<0.01$)on the mosquito abundance as will be seen in the following different collection sites (Tables 1-10).

Although ecology, development, behaviour, and survival of mosquitoes are strongly influenced by climatic factors, temperature, rainfall, and humidity are especially important (Cook, 1996), but in Jazan, according to our study, only rainfall rate has a significant effect ($P<0.01$) and ($r= 0.459$) on mosquitoes activity which was in parallel with the results of Al Ahmed (2010) who reported a close link between mosquito activity and rainfall in the eastern region of KSA as well as the activity of mosquitoes started to increase with the onset of the rainy season, and disappeared during the dry season. Also some authors have observed that the availability of larval habitats (Hayes and Charlwood, 1979; Guimarães *et al.*, 2000) and the abundance of mosquitoes are mainly controlled by rainfall (Guimarães *et al.*, 2001), even in artificially altered environments (Forattini *et al.*, 1996) like PAHS in Brazil. In addition, Silva *et al.* (2010) reported that larval development was influenced by rainfall and the temperature of the 10 days prior to capture.

Gizan

Table 1: Relationship between some ecological factors and monthly collected mosquitoes in Gizan.

Sr.	Month	Temp. °C r=0.025	RH % r=0.028	RR mm r=0.459[s]	W S Km/Hr r =0.013	Total mosquitoes Mean =195.53
1	February 2009	27.8	67	5	3.3	17
2	April 2009	31.5	62.8	3.6	2.6	235
3	May 2009	33.2	64.5	12.5	2.4	190
4	June 2009	33.9	58	3.5	0.9	38
5	July 2009	34.5	61.8	2.2	2.2	77
6	August 2009	32.4	67.8	2.9	1.85	440
7	November2009	28.7	63.5	2.7	5.1	234
8	December2009	28.3	65.8	7.1	6.64	210
9	January 2010	29.9	54.5	9.7	9.5	169
10	February2010	32.1	55.2	5	5.2	36
11	March2010	28.6	66	8.1	5	528
12	April 2010	29.3	60	3.6	4.7	140
13	May 2010	32.3	62.5	12.5	1.5	150
14	June 2010	32.1	68	3.5	1.8	140
15	July 2010	31.6	54	2.2	7.1	120
16	August 2010	32.4	65	2.9	3.4	0
17	September2010	31.2	68.5	8.3	0.2	600

[s]= strong correlation

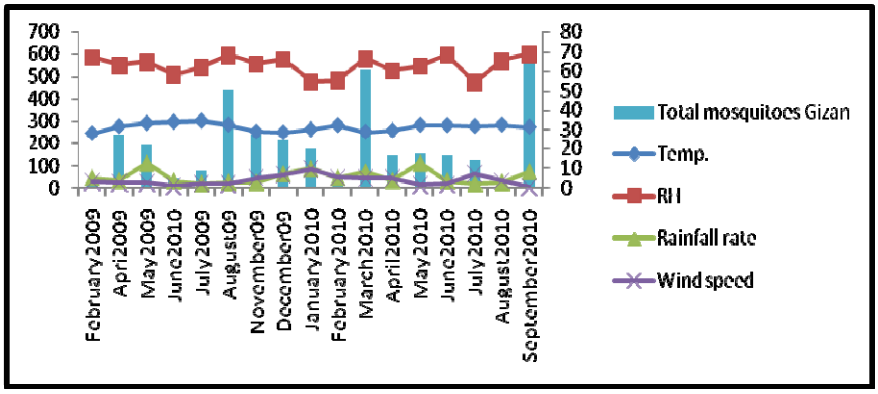


Fig. 2: Effect of ecological factors on mosquitoes abundance in Gizan.

El Arda

Table 2: Relationship between some ecological factors and monthly collected mosquitoes in El Arda.

Sr	Month	Temp. °C	RH %	RR Mm	W S Km/Hr	Total mosquitoes Mean =1219.47
1	February 2009	33.7	68	23	5.3	55
2	March2009	30.1	66	35	10.1	23
3	April2009	30	68	43	2.8	12
4	May2009	30.4	53	99	1.6	0
5	June2009	33.8	67.2	21	2.1	3
6	July2009	31.7	68.3	6	1.7	41
7	August2009	32.8	61.6	0	1.4	192
8	November2009	30.6	55.3	45	4.01	107
9	December2009	28.4	60.4	0	2.8	225
10	January2010	28.4	63.3	0	1.3	184
11	February2010	34.6	53.7	55	3.7	1726
12	April2010	31.5	51	70	1.8	177
13	May2010	31	60	70	2.7	116
14	June2010	31.1	66	27	1.2	300
15	July2010	32	61	21	O.2	200
16	August2010	31.5	59	18	2.5	67
17	September2010	33.5	59	51.5	0	1730

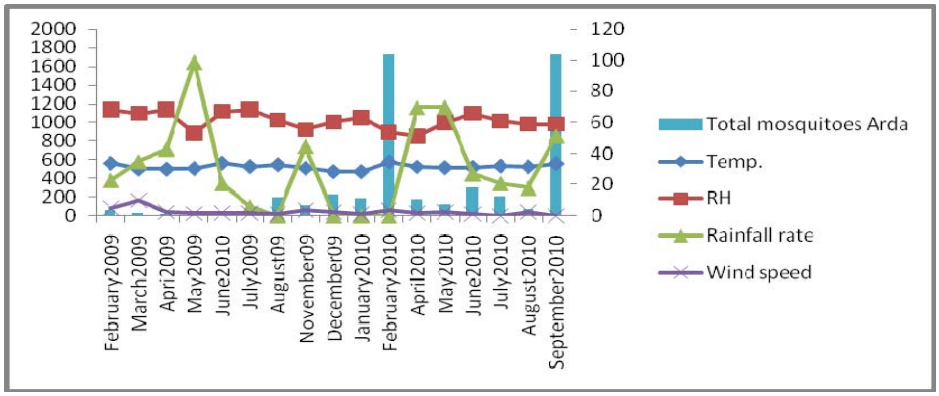


Fig.3: Effect of ecological factors on mosquitoes abundance in El Arda.

Baish

Table 3: Relationship between some ecological factors and monthly collected mosquitoes in Baish.

Sr	Month	Temp. °C	RH %	RR Mm	W S Km/Hr	Total mosquitoes Mean =101.94
1	February 2009	36.7	47	5.9	5.2	2
2	April2009	31.04	56.8	9	2.82	0
3	May2009	30.3	63.8	27.8	3.7	76
4	June2009	32.8	60.7	17.9	0.7	68
5	July2009	32.6	50	3.6	4.5	18
6	August2009	32.9	60.6	4.2	2.7	218
7	November2009	29.1	71	6.1	0.5	107
8	December2009	29.1	82	14.8	3.3	60
9	January2010	32.6	63.5	15	2.2	200
10	February2010	29.6	55.3	5.9	3.35	69
11	March2010	36.6	58	18	0.5	400
12	April2010	32.5	51.5	9	3.5	75
13	May2010	32	68	27.8	1.3	70
14	June2010	31.6	64.3	17.9	1.4	0
15	July2010	32	63	3.6	1.5	55
16	August2010	31.5	61.5	4.2	0.6	115
17	September2010	33.1	64.5	12.5	1.1	200

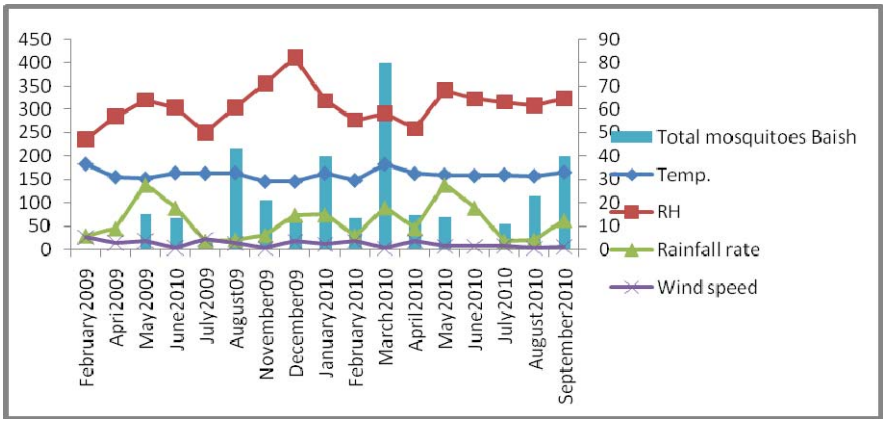


Fig. 4: Effect of ecological factors on mosquitoes abundance in Baish.

Ahad El Masarha

Table 4: Relationship between some ecological factors and monthly collected mosquitoes in Ahad ElMasarha.

Sr	Month	Temp. °C	RH %	RR mm	W S Km/Hr	Total mosquitoes Mean =72.69
1	February2009	35.4	52	0	3.9	81
2	April2009	30.6	70	88.5	2.25	0
3	May2009	34.4	62.3	182	1.3	211
4	June2009	31.2	64.4	60	1.2	0
5	July2009	31	57	52	0.7	97
6	August2009	32	70	36	1.3	23
7	February2010	32.1	57.5	0	7.9	20
8	March2010	31.1	66	57	3.1	171
9	April2010	31.3	55.5	88.5	2.8	3
10	May2010	31.8	48	182	O.6	63
11	June2010	33.1	72	60	0.8	0
12	August2010	30.4	71	36	0.8	76
13	September2010	30.8	72	7.5	0.7	200

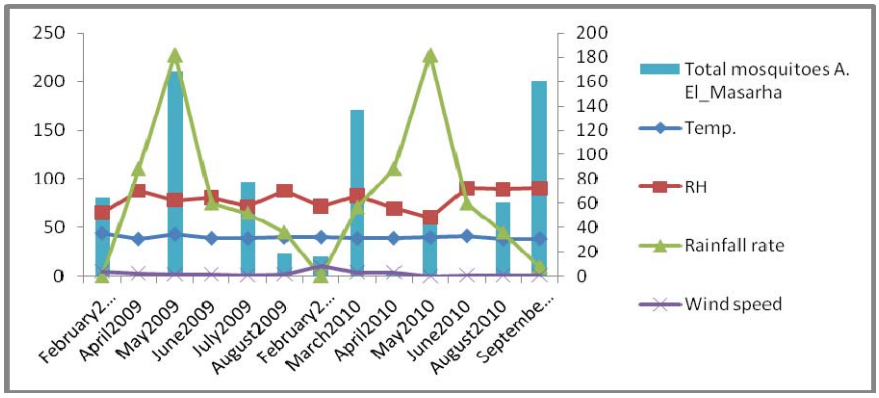


Fig. 5: Effect of ecological factors on mosquitoes abundance in Ahad El massarha.

El Darb

Table 5: Relationship between some ecological factors and monthly collected mosquitoes in El Darb.

Sr	Season	Temp. °C	RH %	RR mm	W S Km/Hr	Total mosquitoes Mean =192.67
1	Summer (July)2009	36	68	13.9	3.5	44
2	Winter(March)2010	34.4	33	17	2.5	319
3	Summer (July)2010	33.6	58	14	0.5	215

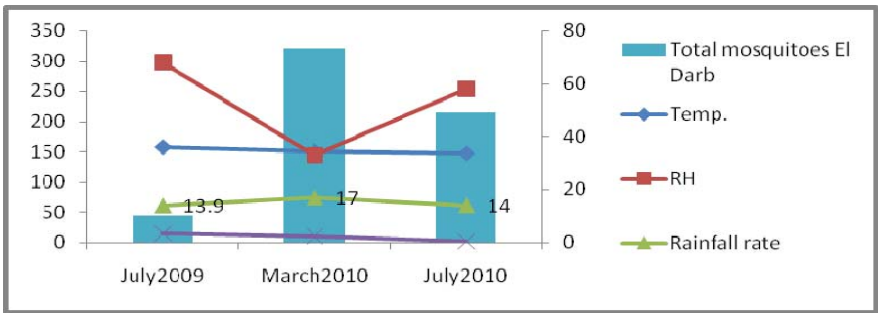


Fig. 6: Effect of ecological factors on mosquitoes abundance in El Darb.

Haroob

Table 6: Relationship between some ecological factors and monthly collected mosquitoes in Haroob.

Sr	Season	Temp. °C	RH %	RR mm	W S Km/Hr	Total mosquitoes Mean =100.25
1	Winter (Feb.)2009	35	68	19	1.4	165
2	Summer (July)2009	31	61	2.5	0.3	25
3	Winter (March)2010	31	68	11.1	28.2	96
4	Summer (July)2010	25.7	55	47.5	2.2	115

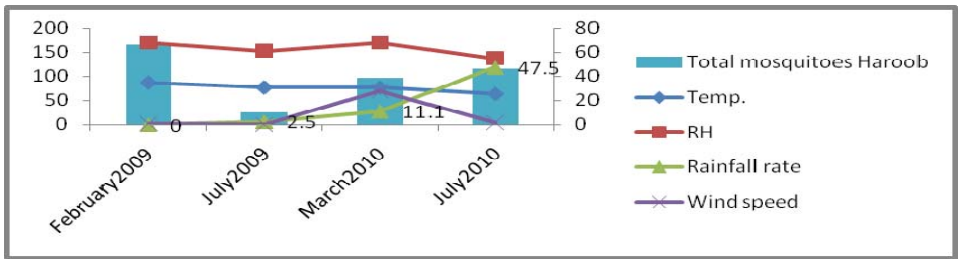


Fig. 7: Effect of ecological factors on mosquitoes abundance in Haroob.

Samta

Table 7: Relationship between some ecological factors and monthly collected mosquitoes in Samta.

Sr	Season	Temp. °C	RH %	RR mm	W S Km/Hr	Total mosquitoes Mean =1304.33
1	Summer(July) 2009	33.7	69	0	1.7	279
2	Winter(March) 2010	35.3	63	9	1	3561
3	Summer(July) 2010	31.3	73	0	0	73

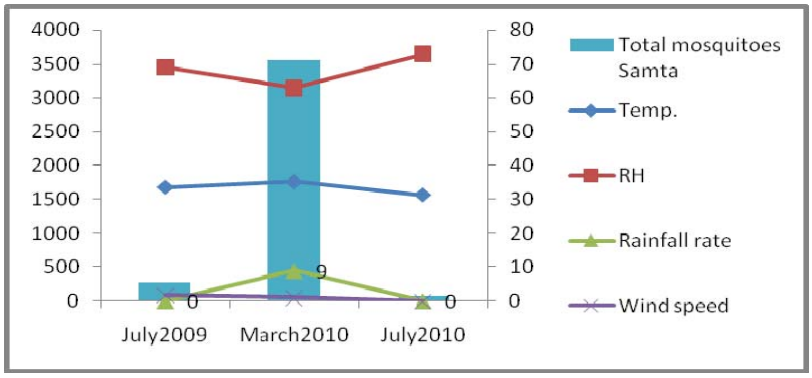


Fig. 8: Effect of ecological factors on mosquitoes abundance in Samta

Dayer Bany Malek

Table 8: Relationship between some ecological factors and monthly collected mosquitoes in Dayer Bany Malek.

Sr	Season	Temp. °C	RH %	RR mm	W S Km/Hr	Total mosquitoes Mean =1678.33
1	Summer(August) 2009	33.3	44	12	2.1	35
2	Winter(March) 2010	27	37	20.8	5	5000
3	Summer (July)2010	29.7	68	8	5	0

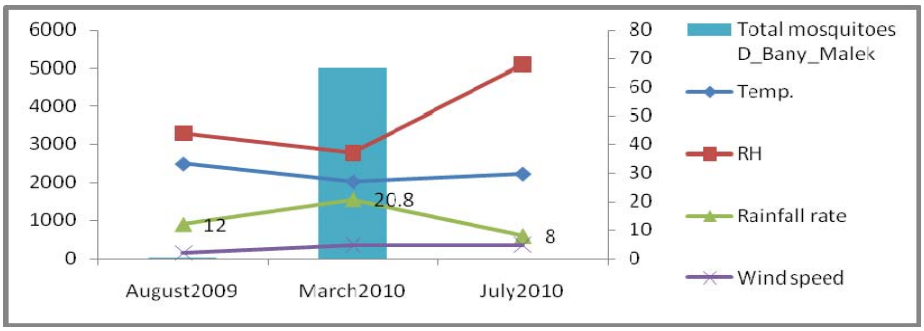


Fig. 9: Effect of ecological factors on mosquitoes abundance in Dayer Bany Malek.

Farasan

Table 9: Relationship between some ecological factors and monthly collected mosquitoes in Farasan.

Sr	Date	Temp. °C	RH %	RR mm	W S Km/Hr	Total mosquitoes Mean =42.20
1	Winter (April)2009	30.3	55	12	2.3	199
2	Winter (May)2010	33.4	61	0	1.7	0
3	Summer (August)2010	32.7	56	0	5.1	0

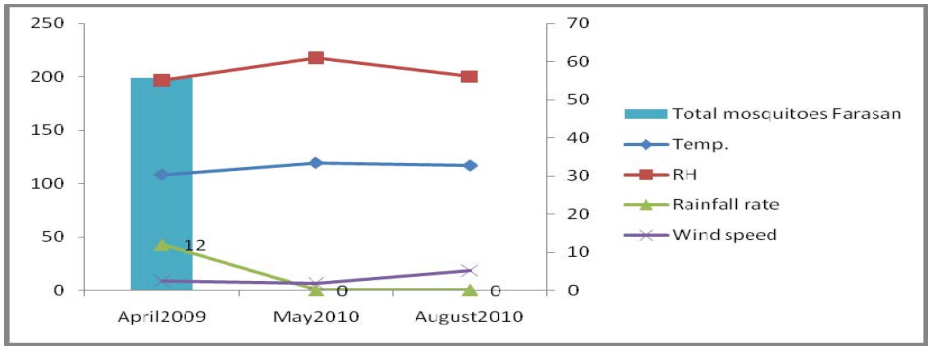


Fig.10: Effect of ecological factors on mosquitoes abundance in Farasan.

Wadi Gizan

Table 10: Relationship between some ecological factors and monthly collected mosquitoes in Wadi Gizan.

Sr	Season	Temp. °C	RH %	RR mm	W S Km/Hr	Total mosquitoes Mean = 6
1	Winter(April)2010	31	57	24	3	12
2	Summer (July)2010	29.3	63	5	0.7	0

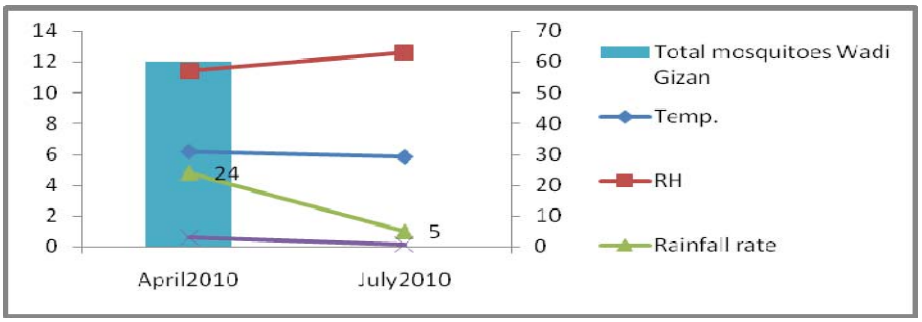


Fig. 11: Effect of ecological factors on mosquitoes abundance inWadi Gizan.

Our work revealed that mosquitoes were available throughout the year and all over the whole Jazan region, but at different densities depending significantly on the rainfall rate in the visited sites: Gizan, Arda, Baish, and Ahad El Massarha. Two peaks of mosquito activity were attained yearly, February to April and July to September, after a rainy season which leads to more breeding sites. Except that population density declined as RR decreased, on the other hand, may be there were some exceptions which will be discussed later.

Frequently Visited Sites

In Gizan, a peak of mosquito activity was attained in April 2009 when RR was 3.6 and the preceding reading for RR was 5 which leaded to more breeding sites. Population density declined as RR decreased but in the next month, although RR reached 12.5, population decreases to 190 which may be because of intensive control applied there in that place (Al Sheik, 2011), raising of temperature to 33.2 ^{0}C or other unknown technical reason. Other peak happened in the period from August to September by increasing of RR that led to the 2nd peak during the study period then declined and so the mosquito population declined also, but the control as well as decreasing of temperature and RH decreased reaching 29.9 and 54.5, respectively prevented the increase in the mosquitoes population although RR was 9.7 during January 2010 which is in agreement with Pinto *et al.* (2009)who found a positive correlation between *Hg. janthinomys* and air humidity in Caxiuanã National Forest in Brazil. The 3rd peak was in March 2010 when RR reached 8.1 and the collected mosquitoes (528) then declined as the RR declined, then reached to the 4th peak in September 2010 recording 600 collected mosquitoes when RR was 8.3.

In El Arda, mosquitoes were available throughout the year but in different densities depending significantly on RR and the other prevailing climatic factors as well as by perennial flow from the mountain streams from Yemen (Al Sheik, 2011). A Peak of mosquito activity was attained in February 2010 when the RR was 55. Population density declined recording 177 although RR increased recording 70 during April 2010. In September 2010, a peak of mosquitoes density took place recording 1730 when the RR was 51.5.

In Baish, a typical positive correlation between mosquitoes density and RR, while starting with low density in February and April 2009, but by increasing RR in May 2009 to 27.8 the population density was 76 and declined by declining the RR in June 2009 recording 68 and 17.9 collected mosquitoes and RR, respectively, and so in July 2009 recording 18 when RR was 3.6. First peak took place in August 2009 when RR increased to 4.2 leading to mosquitoes density 218. In January 2010, mosquitoes density reached 200 when RR was 15 and the preceding month was 14.8 which led to more larval breeding sites. It declined in the next month, February 2010, recording 69 when RR declined to 5.9, but in March 2010, another peak of mosquito population (400) when RR increased to 18. Mosquitoes density was hesitating increasing and decreasing as RR increase and decrease and finally reaching the last peak in September 2010 recording 200 when RR was 12.5.

In Ahad El Massarha, While RR was 0.0, mosquitoes population recorded 88 which indicates the importance of artificial breeding sites. In April and May 2009, RR reached 88.5 and 182, respectively, leading to more breeding sites resulting in collection of 211 adult and larval mosquitoes from different species. It was declined in the next month because of intensive control of mosquitoes, but the month after, July 2009, it was rebuilt giving rise 97 collected mosquitoes when RR was 52. RR declined in the subsequent months leading to decline in the density of mosquitoes. In March 2010, RR reached 57 which raised the population of mosquitoes to171. In

May2010, increased RR, 182, led to increasing collected mosquitoes to 63. Despite the presence of raised RR in June and August 2010, but the increase of mosquito population was in September 2010, 200 collected mosquitoes, as a result of governmental insect control. These results report that the increase in mosquitoes activity was in the rainy months or a little bit time after the rainy months which completely agrees with and corroborates the observations of Charlwood *et al.,* 1995 and Lemasson *et al.,* 1997 that stated that in the dry Savanna of Africa, vector species can have seasonal fluctuations in abundance, declining to low levels in dry seasons and Silva *et al.* (2010) who reported that *Hg. janthinomys* was more abundant in the rainiest and humid months, also because of the availability of larval habitats, as well as the highest abundance was also recorded during the rainy period, Trapido and Galindo (1957) reported catching *Haemagogus* mainly during the rainiest months and Alencar *et al.* (2008) also reported increased population density of this species during the hot and humid months. Pinto *et al.* (2009) found a positive correlation between *Hg. janthinomys* and air humidity in Caxiuanã National Forest in Brazil. They found that mosquito population increased in the humid and rainy months because of the higher availability of larval habitats, Zequi *et al.* (2005) also reported greater abundances of *Li. durhami* during the Summer due to the greater availability of larval habitats.

Occasionally visited sites

El Darb, the 1stoccationally visited site, was visited twice in 3 successive seasons Summer (July 2009), Winter (March 2010) and Summer July 2010. Mosquitoes population was 44 when RR was 13.9 in July 2009 then increased in the next season (March 2010) by increasing the RR reading 319 when RR was 17. In July 2010 mosquitoes declined again by declining the RR reading 14 and 215 RR and collected mosquitoes respectively. From this results mosquitoes activity was increased in El Darb collection site in Winter than that of Summer. This result is in agreement with Ahmed *et al.* (2011) who reported that mosquitoes in, AL-Ahsaa region, Saudi Arabia, are prevalent in both Winter and spring seasons, rarely encountered in Summer, and are found in moderation during the autumn months and Al Ghamdi *et al.* (2008) who observed relatively low activity of mosquitoes in Jeddah governorate during Summer months of July and August when the average temperature was above 40^0C.

Haroob was visited twice in 4 successive seasons, Winter (February 2009), Summer (July 2009), Winter (March 2010) and Summer (July 2010). Mosquitoes population were 165 when RR was 19 in the 1st Winter (February 2009) then declined in the next Summer (July 2009) (25) when RR was 2.5 then increased in the next season (March 2010) by increasing the RR reading 96 while RR increased also to 11.1. In July 2010 although it is considered as Summer season but when RR increased to 47.7 mosquitoes density also increased to 115. Mosquitoes activity was increased in Haroob collection site in Winter than that of Summer in the year of 2009 but in the Summer 2010 mosquitoes still increased because of increased RR which leaded to more breeding sites which completely agree with and corroborate the observations of Silva *et al.* (2010) who reported that *Hg. janthinomys* was more abundant in the rainiest and humid months, also because of the availability of larval habitats, as well as the highest abundance was also recorded during the rainy period.

Samta was visited twice in 3 successive seasons, Summer (July 2009), Winter (March 2010) and Summer (July 2010). Mosquito population was present all seasons because most of breeding sites were artificial but in the same time it increased significantly by RR. While there was no rains in Summer 2009 season (RR=0.0),

collected mosquitoes recording 279. In March 2010 total mosquitoes increased by increasing RR while RR was 9.0, collected mosquitoes was 3561. Summer 2010 when RR was declined to 0.0 but mosquitoes density did not reaches 0.0 but recorded 73 depending on artificial breeding sites which not related for the RR (Al-Sheik, 2011).

Dayer Bany was visited twice in 3 successive seasons, Summer (August 2009), Winter (March 2010) and Summer (July 2010). Mosquitoes population were present in low density Summer (August 2009) while RR was 12, collected mosquitoes recorded 35. In March 2010 total mosquitoes increased by increasing of RR reaching the peak, while RR was 20.8, collected mosquitoes were 5000. Summer 2010 when RR was declined to 8.0, mosquitoes density reached 0.0.

Farasan was visited twice in 3 successive seasons also, Winter (April 2009), Winter (May 2010) and Summer (August 2010). Mosquitoes population were present in Summer (April 2009) when rains was present, 199 and 12 for collected mosquitoes and RR respectively. On the other hand the absence of rains in Farasan leaded to absence of mosquitoes as in May 2010 and August 2010 recording 0.0 for RR and collected mosquitoes.

Wadi Gizan was considered as 6^{th} occasionally visited site and visited twice in 2 successive seasons Winter (April 2010) and Summer (July 2010). It was a target for more than one organization for the control of mosquitoes so the collected mosquitoes were so low. In April 2010 Mosquitoes population was 12 when RR was 24 and in July 2010 collected mosquitoes was 0.0 while RR was 5 due to the intensive control from more than one organization.

These results of occasionally visited sites revealing that the activity of mosquitoes in Jazan region was increased in Winter than Summer season which explained by the effect of the high temperature on the development of mosquitoes as well as low RR. Cook (1996) stated that ecology, development, behavior, and survival of mosquitoes are strongly influenced by climatic factors. Temperature, rainfall, and humidity are especially important, but others, such as wind and the duration of daylight, can also be significant. In Al-Ahsaa region, Ahmed *et al.* (2011), reported that mosquitoes are prevalent in both Winter and spring seasons, rarely encountered in Summer, and are found in moderation during the Autumn months and in Jeddah Al Ghamdi *et al.* (2008) observed relatively low activity during Summer months of July and August when the average temperature was above 40^0C. Al Ahmed (2010) who reported that the abundance of mosquitoes in the Eastern region of KSA is closely linked with rainfall and humidity that agrees with our findings. In Al Dammam District, A peak of mosquito activity was attained in July and other one in March because the rainfall during January–April provided more breeding sites for mosquitoes which lead to an increase in population density during the subsequent months. On the other hand seasonal abundance of mosquitoes in the second location, Hafar Al-Batin District, The activity of mosquitoes started to increase in November with the onset of the rainy season, and disappeared during the dry season (June–September). Seasonal abundance of adult mosquitoes in Al Ahsa Area, The increase in rainfall during January-March provided more larval breeding sites, and a peak of activity was attained in June. The population density of mosquito started to decrease with the onset of dry season in July. Finally especially in Jazan region Abundance of mosquitoes not only related to the rain fall but also breeding sites for may sustained by perennial flow from the mountain streams. Thus, *An. arabiensis*was able to breed almost every month even when rainfall was lower than average (Al Sheik, 2011).

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