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Monthly prevalence and diversity of mosquitoes (Diptera: Culicidae) in Fars Province, Southern Iran

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ABSTRACT

Objective: To get new data about the ecology of mosquitoes, which would be valuable to develop programs for future provision of mosquito controls in the study area.
Methods: During April to September 2012, larvae of mosquitoes were collected from six counties in south of Fars Province using dipping method. Characteristics of larval breeding places were considered based on water conditions. Species diversity was examined in terms of alpha and beta measures, with the intent of comparing mosquito diversity according to the typology of regions.
Results: During this investigation, totally, 5 057 larvae of mosquitoes belonging to 5 genera and 17 different mosquito species were recognized, namely, *Anopheles dthali, Anopheles fluviatilis, Anopheles stephensi, Anopheles superpictus, Culex quinquefasciatus* (*Cx. quinquefasciatus*), *Culex mimeticus, Culex perexiguus, Culex pipiens* (*Cx. pipiens*), *Culex tritaeniorhynchus, Culex theileri* (*Cx. theileri*), *Culex tritaeniorhynchus, Culex sinaiticus, Culex torrentium, Culex modestus, Ochlerotatus caspius, Culiseta longiareolata* and *Aedes vexans* (*Ae. vexans*). This is the first record of *Ae. vexans*, *Culex perexiguus* and *Culex modestus* in the Province. *Cx. pipiens* (27.3%), *Cx. theileri* (15.9%) and *Cx. quinquefasciatus* (9.4%) were the most abundant species found respectively. *Cx. pipiens* reached the highest density in August and July, while *Cx. theileri*, *Cx. quinquefasciatus* and *Ae. vexans* were found in high numbers in June. Diversity analysis indicated the highest species diversity in the Mohr County (Margalef index of 1.41 and Shannon index of 1.7) and the lowest species diversity in the Lamerd County (Margalef index of 0.33 and Shannon index of 0.38).
Conclusions: Regarding to this research, there are some potential vectors of medical and veterinary importance in Fars Province. Results of the present study may serve as a basis for risk assessment of emerging mosquito-borne diseases.

1. Introduction

Mosquitoes are remarkably adapted to coexist with human and domestic animals and they are one of the largest vectors of disease in the world[1]. Mosquitoes (Culicidae) are the most important vectors of public health interest due to their involvement in the transmission of various infectious diseases[2,3]. Some mosquito-borne diseases such as malaria, West Nile and Sindbis viruses, dengue fever and dirofilariasis have been reported in Iran[2,4]. Currently, rural areas of Fars Province are part of the malarious zones in Iran[5]. Malaria is a major health problem in Iran and its outbreaks usually occur after the rainy season[6]. *Dirofilaria immitis* (*D. immitis*) (dog heartworm) has been reported from the Fars Province[7]. *Culex theileri* (*Cx. theileri*) is a known vector of *D. immitis* in Iran[2]. Therefore, due to the importance of malaria and *Dirofilaria* in Fars Province and the

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possibility of Culicidae mosquitoes to transmit other vector-borne diseases, exigency of this study is highlighted.

In order to measure disease transmission, a good information about these vectors is essential. To reach this objective, entomological surveys are necessary. According to a new research, mosquitoes were classified as 2 subfamilies and 112 genera in the world[8]. According to a recent study, the checklist of the mosquitoes of Iran comprises 2 sub-families (Anophelinae and Culicinae), 64 species and 3 sub-species belonging to seven genera (*Anopheles, Uranotaenia, Culiseta, Coquillettidia, Culex, Aedes* and *Ochlerotatus*)[9]. Seven species of the genus *Anopheles* Meigen [*Anopheles sacharovi* Favre, *Anopheles maculipennis* Meigen s.l., *Anopheles culicifacies* Giles s.l., *Anopheles dthali* Patton (*An. dthali*), *Anopheles fluviatilis* James s.l. (*An. fluviatilis*), *Anopheles superpictus* Grassi (*An. superpictus*), *Anopheles stephensi* Liston (*An. stephensi*)] are known malaria vectors in Iran and *Anopheles pulcherrimus* Theobald is considered a potential vector of malaria in the south-eastern area of the country[5,9].

Recently, *Anopheles hyrcanus* was reported as a possible vector of malaria using the PCR technique in Guilan Province[10].

There is scattered information about the mosquito fauna in Iran. Aaim *et al*. reported the fauna of *Culex* mosquitoes in Iran[11]. Checklist of the culicine mosquitoes in Iran was reported by Zaim and Cranston in 1986[12]. The fauna and ecological characteristics of Culicidae mosquitoes in Isfahan, Guilan, Kurdistan, Sistan and Baluchistan and Hormozgan Provinces have been reported, previously[13-18]. Updating knowledge of the culicinae fauna of the Fars Province has been a priority for many years and until now, 16 species of culicine mosquitoes have been recorded in Fars Province[19]. Gathering baseline data on population composition, abundance and diversity of mosquito species are necessary so that their roles as vectors of various human and animal diseases may be better understood[20].

The abundance of vectors mosquitoes is strongly affected by seasonal climate variations and density-dependent patterns. Change of climate can accelerate or procrastinate the mosquitoe development and availability of breeding places[20]. Changes of the abundance and diversity of mosquitoes can increase the risk of disease transmission[21,22].

Species diversity in an environment was indicated by numbers of different life forms. It is defined and measured as an attribute that has two components (evenness and richness). Biodiversity can be measured at alpha and beta scales. Alpha diversity is defined as the specific richness of individuals within a habitat unit. Beta diversity is defined as expression of diversity between habitats[23]. Therefore, the main objective of our study was to determine the ecology of mosquitoes in the south part of Fars Province.

2. Materials and Methods

2.1. Study area

Fars is one of the 31 provinces of Iran, located in the southern part of the country (29.62° N, 52.53° E). Due to topographic characters, there are three distinct climatic parts of this province. The first part is hilly area in the north and northwest of the province, with considerable vegetation covering. This part has a moderate temperature with 400–600 mm of precipitation annually. The second part is central part of the province with a relatively moderate temperature and hot and dry weather in summer. The average of annual precipitation in this part is around 200–400 mm. The third part is the lowland of south and southeast regions of the province with moderate temperature in winter and very hot and wet weather in summer. The average rainfall of this part is below 200 mm annually. The study was carried out from April to September 2012 in six counties (Darab, Khonj, Lamerd, Larestan, Mohr and Zarindasht) in the south part of Fars Province.

To develop the study, 25 sites were selected in the different topographical areas (Figure 1). In the present study, total rainfall, maximum and minimum temperature of collection sites were shown in Table 1.

Table 1

Ambient temperature and total rainfall of these counties in Fars Province, from April to September 2012.

Counties		Month					
		April	May	June	July	August	September
Larestan	Minimum temperature (°C)	12.1	20.3	21.4	24.2	22.7	18.1
	Maximum temperature (°C)	37.3	42.1	44.6	44.1	44.1	42.4
	Mean temperature (°C)	24.2	31.3	33.4	36.2	32.4	31.4
	Total rainfall (mm)	30.0	0.5	0.0	0.0	22.0	0.0
Lamerd	Minimum temperature (°C)	12.5	18.6	18.3	21.1	22.5	18.6
	Maximum temperature (°C)	39.3	42.3	45.3	47.3	47.4	41.8
	Mean temperature (°C)	29.2	33.1	36.4	38.1	33.5	36.7
	Total rainfall (mm)	12.0	2.0	0.0	0.0	3.0	0.0
Zarindasht	Minimum temperature (°C)	10.5	15.2	19.2	21.8	21.3	16.2
	Maximum temperature (°C)	34.7	39.1	42.3	43.1	43.7	41.6
	Mean temperature (°C)	23.2	30.5	33.5	36.9	33.2	31.4
	Total rainfall (mm)	48.0	2.0	0.0	3.0	24.0	1.0
Darab	Minimum temperature (°C)	8.5	14.8	16.6	20.3	21.7	16.2
	Maximum temperature (°C)	33.8	40.4	42.7	45.5	43.8	40.7
	Mean temperature (°C)	21.2	29.3	33.1	36.2	34.2	30.2
	Total rainfall (mm)	38.0	11.0	0.5	19.0	2.0	0.5
Khonj	Minimum temperature (°C)	13.4	15.1	16.6	19.1	24.5	21.4
	Maximum temperature (°C)	36.2	40.3	41.8	43.3	44.2	40.3
	Mean temperature (°C)	27.2	31.3	32.7	35.6	36.2	36.2
	Total rainfall (mm)	21.0	1.0	0.0	0.0	8.0	0.0
Mohr	Minimum temperature (°C)	13.2	17.6	18.5	20.5	22.5	19.5
	Maximum temperature (°C)	38.7	39.4	44.2	46.3	47.3	39.7
	Mean temperature (°C)	29.4	31.2	35.1	37.6	33.2	32.8
	Total rainfall (mm)	9.0	1.0	0.0	0.0	0.8	0.0

2.2. Mosquito collection and taxonomic identification

In order to study the ecology of mosquitoes, sampling was carried out by dipping technique with a metal dipper for collecting larvae. The mosquito larvae were collected from different breeding sites such as irrigation channels, rain pools, wells and streams. Four scoops were taken from each breeding site (350 mL each). Larval investigation was conducted two times a month over the time of survey[13,14]. All the samples were brought to the laboratory of the Entomology Department, Shiraz University of Medical Sciences. The mosquito larvae were preserved in 75% ethanol and the microscopic slides were prepared using the Faure's medium after one week[2,13]. Microscope was used for the taxonomic study and identification, up to the species level using taxonomic keys available in literature[9]. Abbreviations of mosquito names were cited based on Azari-Hamidian and Harbach[24].

2.3. Species diversity and statistical analysis

Diversity studies (alpha diversity) were conducted separately for each county by calculating classic diversity indexes: Margalef's $(S-1)/\ln N$ [S = total number of species and N = total number of individuals) and Shannon diversity index ($H' = -[\Sigma(pi \ln pi)]$) and the latter was commonly used to characterize species diversity in a community, accounting for both abundance and evenness of the species present[23,25]. Equitability index was also used to measure the evenness with which individuals were divided among the taxa present.

Two indexes were used for beta diversity (similarity and

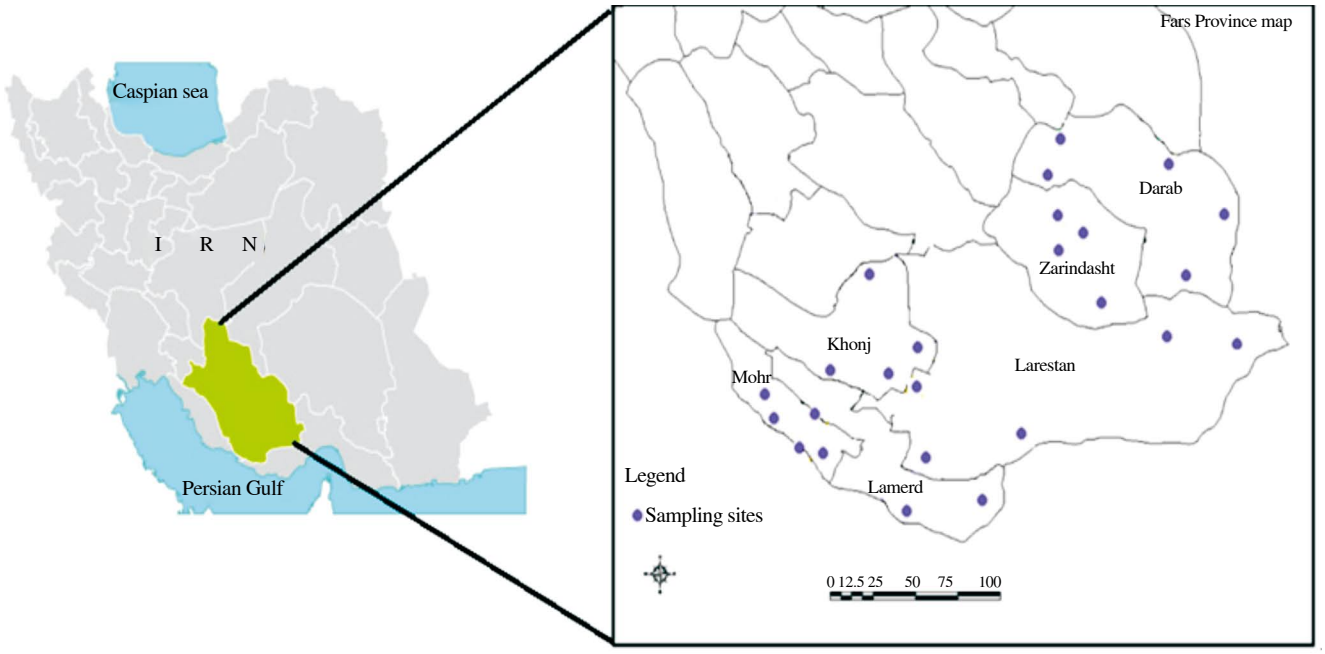

Figure 1. Map of Iran, highlighting the position of Fars Province and showing distribution of sample sites. Data imported from GPS Software.

dissimilarity): Jaccard's index (j = a/a + b + c), where a represents the number of common species between habitats; b represents the number of unique species for habitat 1 and c represents the number of unique species for habitat 2 and Whittaker index, $W = S/[(2a + b + c) - 1]$), where S represents total number of species; a represents the number of common species between habitats; b represents the number of unique species for habitat 1 and c represents the number of unique species for habitat 2[23,24]. Data were analyzed using PAST software version 3.14 (Paleontological Statistics Software Package).

3. Results

3.1. Species composition and abundance

In the present investigation, totally, 5 057 specimens belonging to 17 different mosquito species and 5 genera were collected and identified, as follows: *An. dthali, An. fluviatilis, An. stephensi, An. superpictus, Culex quinquefasciatus* (*Cx. quinquefasciatus*), *Culex mimeticus* (*Cx. mimeticus*), *Culex perexiguus* (*Cx. perexiguus*), *Culex pipiens* (*Cx. pipiens*), *Culex tritaeniorhynchus* (*Cx . tritaeniorhynchus*), *Culex theileri* (*Cx. theileri*), *Culex tritaeniorhynchus* (*Cx. tritaeniorhynchus*), *Culex sinaiticus* (*Cx. sinaiticus*), *Culex torrentium* (*Cx. torrentium*), *Culex modestus* (*Cx. modestus*), *Ochlerotatus caspius* (*Oc. caspius*), *Culiseta longiareolata* (*Cs. longiareolata*) and *Aedes vexans* (*Ae. vexans*) (Table 2). *Cx. pipiens* (27.3%), *Cx. theileri* (15.9%) and *Cx. quinquefasciatus* (9.4%) were the most frequent species in the province. The composition of other species are as follows: *Oc. caspius* (0.09%), *Cx. sinaiticus* (0.1%), *An. fluviatilis* (0.1%), *Cx. torrentium* (0.3%), *An. superpictus* (2.3%), *An. stephensi* (2.8%), *An. dthali* (3.4%), *Cx. perexiguus* (3.7%), *Cx. mimeticus* (3.8%), *Ae. vexans* (4.1%), *Cx. modestus* (5.7%), *Cs. longiareolata* (5.9%), *Cx. tritaeniorhynchus* (6.4%) and *Cx. tritaeniorhynchus* (8.7%). The observations on species distribution of mosquitoes showed that the most distribution was related to *An. dthali* and it was distributed in 5 counties of the total 6 counties. *Ae. vexans*, *Cx. perexiguus* and *Cx. modestus* were recorded from the Fars Province for the first time. The species composition and monthly variation of mosquitoes recovered from all counties surveyed during April to September were summarized in Figure 2–7.

Table 2
Distribution of mosquitoes collected in six counties of Fars Province, Iran in April-September 2012.

Species	Khonj	Mohr	Larestan	Darab	Zarindasht	Lamerd
An. dthali	+	+	+	+	+	-
An. stephensi	+	+	-	+	-	+
An. fluviatilis	-	+	-	-	-	-
An. superpictus	-	+	+	-	-	-
Cx. quinquefascias	+	-	-	+	-	-
Cx. mimeticus	+	+	-	-	-	-
Cx. perexigus	+	-	-	+	+	+
Cx. pipiens	-	+	-	-	+	+
Cx. tritaeniorhyns	-	-	-	+	-	-
Cx. theileri	-	+	-	+	-	-
Cx. bitaeniorhyns	-	-	+	-	-	-
Cx. sinaiticus	-	+	-	-	-	-
Cx. torrentium	-	+	-	-	-	-
Cx. modestus	-	+	+	-	+	-
Oc. caspius	+	-	-	-	-	-
Cs. longiareolata	-	+	-	+	-	-
Ae. vexans	-	-	-	+	-	-

The data in Figure 2 showed that mosquitoes belonging to *Culex* genus were the most dominant in Khonj County. *Cx. quinquefasciatus* was the dominant species among other species with 68.7%, whereas *An. dthali* species came in the second order with 14.8%; while *An. stephensi*, *Cx. perexiguus* and *Cx. mimeticus* came after that with 7.8%, 7.1% and 0.9%, respectively; the last species was *Oc. caspius* where came in the last rank with 0.7%. The mosquito individuals appeared from the beginning of study (April) with 51 individuals, then increased in May and June to make a peak with 253 individuals in June, where the average temperature was 32.7 ˚C; then the population numbers decreased in July to September

with the increased temperature. *An. dthali* reached the highest density in May. *Cx. mimeticus* was only reported in August and September with a total of 4 and 2 specimens, respectively.

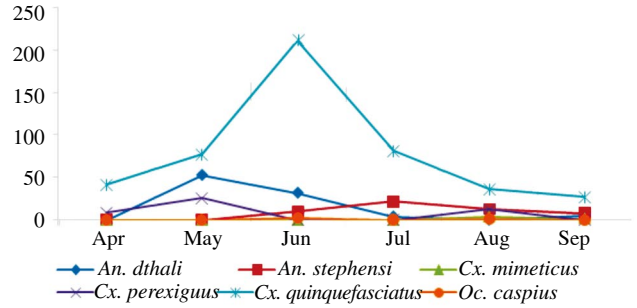

Figure 2. Monthly prevalence of mosquitoes in Khonj County, Fars Province in 2012.

The data in Figure 3 showed that mosquitoes belonging to *Culex* genus were the most dominant in Mohr County. *Cx. theileri* was the dominant species among other species with 33.3%, whereas *Cx. pipiens* species came in the second order with 29.2%; the last species was *An. fluviatilis* where came in the last rank with 0.5%. The mosquito individuals appeared from the beginning of study. *Cx. mimeticus* reached the highest density in May, when the average temperature was 31.2 ℃. The main peaks for *An. superpictus*, *Cx. pipiens* and *Cs. longiareolata* were in August, when the average temperature was 33.2 ℃.

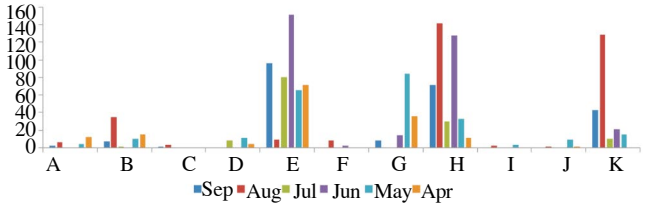

Figure 3. Monthly prevalence of mosquitoes in Mohr County, Fars Province in 2012.

A: *An. dthali*; B: *An. superpictus*; C: *An. fluviatilis*; D: *An. stephensi*; E: *Cx. theileri*; F: *Cx. modestus*; G: *Cx. mimeticus*; H: *Cx. pipiens*; I: *Cx. sinaiticus*; J: *Cx. torrentium*; K: *Cx. longiareolata*.

The data in Figure 4 showed that *Cx. bitaeniorhynchus* was the most abundant species in Larestan County with 76.9%, while *Cx. modestus* and *An. superpictus* species came after that with 13.2% and 8.1%, respectively; the last species was *An. dthali* where came in the last rank, with 1.8%. The mosquito individuals appeared from May with 259 individuals to make the first peak, where the average temperature was 31.3 ℃, after that the population density decreased in Jun to August then increased again in September to make the the second peak with 113 individuals, when the temperature was similar to the first peak (31.4 ℃). The lowest number of mosquitoes was in April and July. *Cx. modestus* reached the highest density in August, when the average temperature was 32.4 ℃. The main peak for *An. superpictus* was in May.

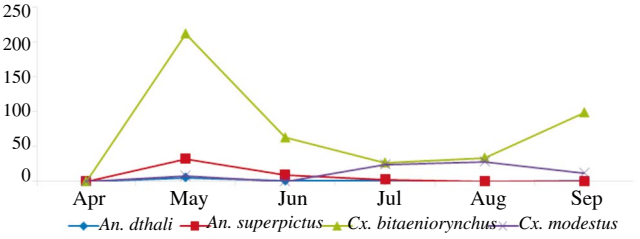

Figure 4. Monthly prevalence of mosquitoes in Larestan County, Fars Province in 2012.

The data in Figure 5 showed that *Cx. theileri* was the dominant species among other species with 32.1%, whereas *Cx. tritaeniorhynchus* species came in the second order with 31.9%; the last species was *An. stephensi* with 1.6%. The mosquito individuals appeared from the beginning of April with 59 individuals, then increased in May and Jun to make the first peak, after that the population density decreased in July then increased again in August to make the second peak with 229 individuals, when the mean temperature reached 34.2 ℃. *Ae. vexans* was abundant in June, when the rains were coming to an end. The main peaks for *Cx. theileri* and *Cx. tritaeniorhynchus* were in Jun and August, respectively.

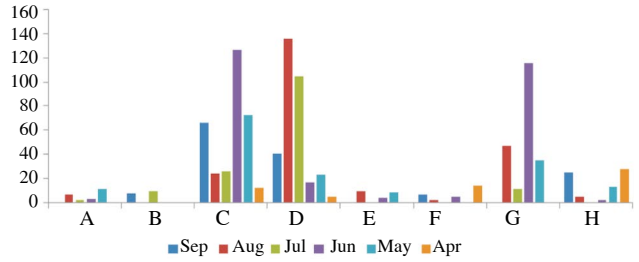

Figure 5. Monthly prevalence of mosquitoes in Darab County, Fars Province in 2012.

A: *An. dthali*; B: *An. stephensi*; C: *Cx. theileri*; D: *Cx. tritaeniorhynchus*; D: *Cx. mimeticus*; E: *Cx. perexiguus*; F: *Ae. vexans*; G: *Cs. longiareolata*.

The data in Figure 6 showed that *Cx. pipiens* was the dominant species among other species with 49.4% in Zarindasht County, whereas *Cx. modestus* species came in the second order with 32%; the last species was *An. dthali* with 2.6%. The mosquito individuals appeared from May with 27 individuals, then increased in Jun and July to make a peak with 265 individuals in July, when the mean temperature was 36.9 ℃. After that, the population density increased in July then decreased again in August and September. Mosquitoes were not collected in April, when rainfall was heavy. *Cx. modestus* reached the highest density in August, similar to what had already been mentioned in Larestan.

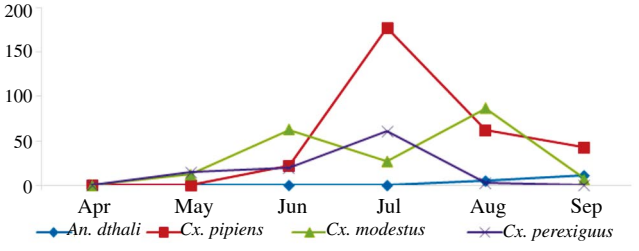

Figure 6. Monthly prevalence of mosquitoes in Zarindasht County, Fars Province in 2012.

The data in Figure 7 showed that *Cx. pipiens* was the dominant species among other species with 91% in Lamerd, whereas *An. stephensi* came in the second order with 6.6%; the last species was *Cx. perexiguus* with 2.4%. The mosquito individuals appeared from April with 82 individuals, then increased in May to make the first peak, after that the population density decreased in Jun and July then increased again in August to make the second peak with 224 individuals, when the mean temperature was 33.5 ℃. Most of the mosquitoes species were collected from Mohr County (28.3%), followed by Darab (20.2%), Lamerd (14.3%), Khonj (13.9%), Zarindasht (12.1%) and Larestan (11.2%). The effect of ambient temperature on the monthly prevalence of mosquitoes was shown in Figure 8. Overall, in this study there was no significant

relationships between mean temperatures and abundance of mosquitoes (P = 0.617). In the present study, *Cx. modestus*, *Cx. sinaiticus* and *Oc. caspius* were only collected from natural habitats. *Cx. tritaeniorhynchus*, *Cx. quinquefasciatus*, *Cs. longiareolata* and *An. superpictus* were collected mostly in artificial habitats. *Cx. bitaeniorhynchus*, *Cx. mimeticus*, *Cx. pipiens*. *Cx. modestus*, *An. superpictus*, *An. fluviatilis* and *An. dthali* were found mostly in permanent and clear water.

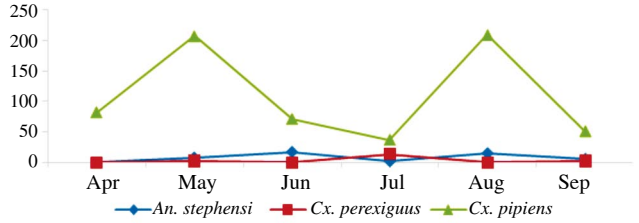

Figure 7. Monthly prevalence of the mosquitoes in Lamerd County, Fars Province in 2012.

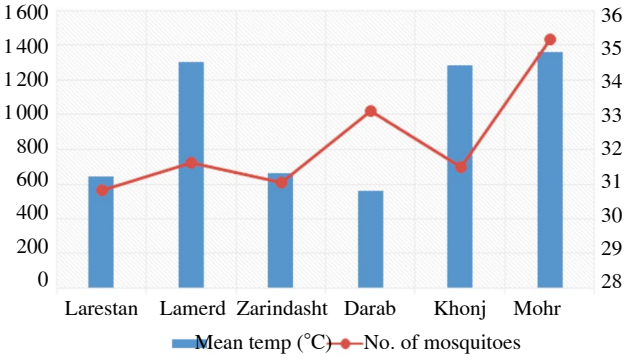

Figure 8. The effect of temperature on monthly prevalence of mosquito larvae in the south of Fars Province from April-September 2012.

3.2. Mosquito species diversity

According to the analysis of α biodiversity indexes (Figures 9 and 10), it was possible to observe a greater species richness and diversity in Mohr (Margalef index = 1.41 and Shannon index = 1.7), while in Lamerd, this was the lowest (Margalef index = 0.33, Shannon index = 0.38). Shannon index highlighted that in Lamerd, *Cx. pipiens* strongly dominated the rest of species present in the community. Something similar occurs in the case of Larestan, where *Cx. bitaeniorhynchus* developed a strong influence. Finally, greater evenness degree could be observed in Zarindasht (equitability = 0.78), because the most dominant species did not show such a strong influence as in the other cases (Figure 11). The analysis of β biodiversity showed that Darab and Khonj were the closest categories in their specific composition (Whittaker index = 0.428 57) (Table 3).

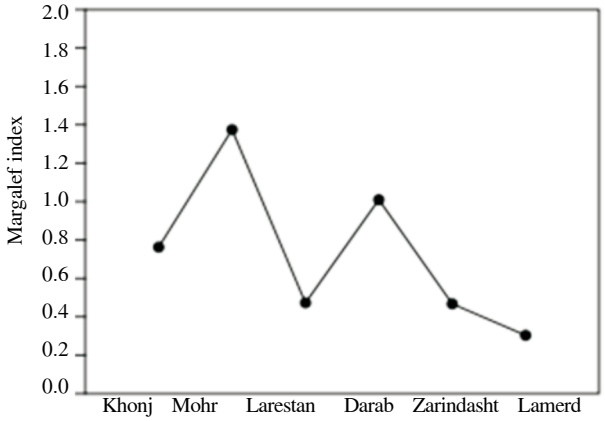

Figure 9. Margalef index values based on the larval abundance within each county.

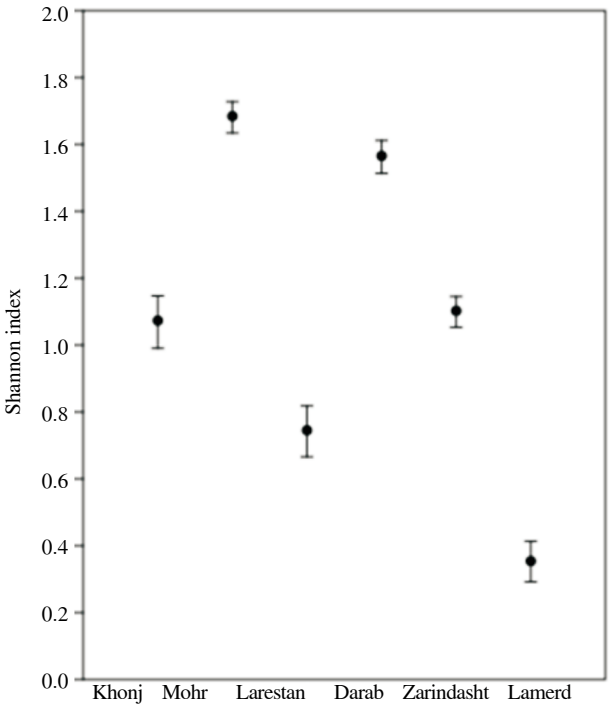

Figure 10. Shannon index values for each county.

Table 3

Determining similarity or dissimilarity between locations based on Whittaker index.

	Khonj	Mohr	Larestan	Darab	Zarindasht	Lamerd
Khonj	0	0/64 706	0/8	0/42 857	0/6	0/55 556
Mohr	0/64 706	0	0/6	0/47 368	0/6	0/71 429
Larestan	0/8	0/6	0	0/83 333	0/5	1
Darab	0/42 857	0/47 368	0/83 333	0	0/66 667	0/63 636
Zarindasht	0/6	0/6	0/5	0/66 667	0	0/42 857
Lamerd	0/55 556	0/71 429	1	0/63 636	0/42 857	0

1: Complete difference.

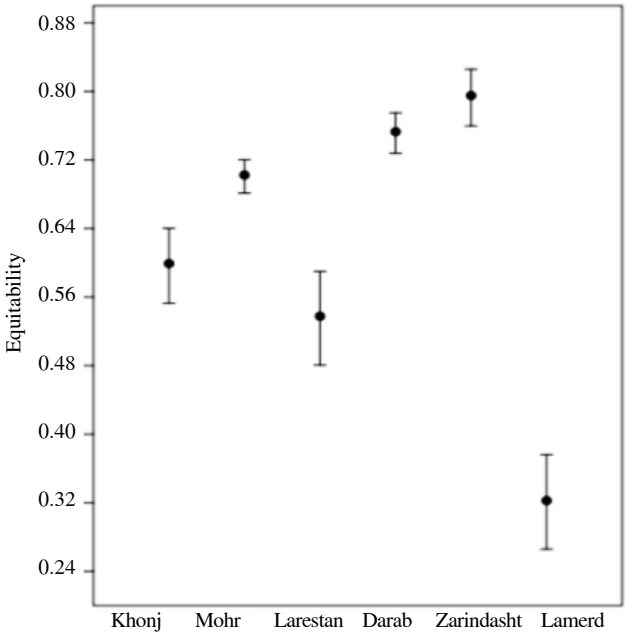

Figure 11. Equitability values based on the larval abundance within each county.

4. Discussion

In the present investigation, totally 5 057 mosquito specimens were found. Four *Anopheles* species were collected in this investigation, including *An. dthali*, *An. stephensi, An. superpictus* and *An. fluviatilis*.

An. fluviatilis is now recognized as a species complex comprising at least three sibling species (S, T and U species)[26]. In the previous study, Naddaf *et al*. found *An. fluviatilis* species U in the Fars Province[27]. This species is responsible for transmission of malaria along the foothills of the Zagros chain that stretches from south to southeast in Iran[28]. In this study, among four *Anopheles* species, *An. fluviatilis* (1.6%) was the lowest prevalent species. This species was reported only in Mohr. The monthly activities of this species in the Isfahan Province was reported from September[29]. *An. fluviatilis* in the present study was collected from August and September. In the study of Maghsoodi *et al*., it was collected from April to September[30]. Study in Hormozgan Province showed that *An. fluviatilis* larvae were found in slow-running water, river margins, vast marshes, pits in stony river beds, and pits around spring and irrigation drains with vegetation (Graminae plants)[31]. Larvae of *An. fluviatilis* were collected from larval breeding sites without plants, clean water and with a sandy bottom, within the southern part of Iran and this agrees with our findings[32].

An. stephensi is the main vector of malaria in the malarious area of Southern Iran and reported from Ilam, Bushehr, Fars, Hormozgan, Kermanshah, Kerman, Kohgiluye and Buyerahmad, Khuzestan, Lorestan, Sistan and Bluchestan provinces[33]. During the spring and autumn, *An. stephensi* population has two main seasonal peaks[34]. In the study of Mehravaran *et al*., the main peak of this species ocurred in May and this agrees with our findings at Mohr County[35]. The knowledge about the seasonal peaks of vectors can assist to combat against mosquitoes when epidemics occur. This species breeds in a wide range of both natural and artificial habitats such as pools, seepage canals, wells and stream bed pool[36]. In the study of ecology of mosquitoes in Aligudarz County in Western Iran, larvae of this species were not found in artificial larval nests. The dominant natural breeding place was a river side[37]. This finding is not similar to the present study. In the present study, larvae of *An. stephensi* were mostly caught from the larval breeding places without plants, full sunlight, with clean water and sandy bottom. This finding is identical with the study of Hanafi-Bojd *et al*.[32].

An. superpictus is considered as a major malaria vector in the central plateau and the secondary vector in the southern parts of Iran[28]. This species has a widespread distribution and two distinct morphological forms (A and B) of this species reported from Iran[38]. The monthly activity of this species in Isfahan Province was started from July to August[29]. In our study, the monthly activity in Larestan was started from May to July and in Mohr was recorded from April, May and July to September. The main peaks for this species were in May and August in Larestan and Mohr, respectively. The study of seasonal dynamics of mosquitoes in Farsan County, Shahrekord showed that seasonal activity of *An. superpictus* began from mid-May and continued until mid-October and reached its peak in July[39]. The study in Kurdistan, Western Iran, showed that *An. superpictus* (57.7%) was more common anopheline species in this area and was active in July to October[14].

An. dthali is widespread in semi-arid regions from the North Africa to Baluchistan, Northwest Pakistan and Southern Iran[40]. In this study, among four *Anopheles* species, *An. dthali* (38.9%) was the most prevalent species. It is a secondary vector of malaria in Hormozgan Province, Southern Iran[34]. The monthly activity of this species in Jask County in Hormozgan Province was reported during all months of the year[41]. In the present study, the monthly activity of *An. dthali* in Darab County was started from May to August. The larval habitats of this species in Hormozgan Province were in springs, edge of rivers and holes around the springs with or without plants, irrigation channels and the pits of river bed[42]. In this study, larval habitats of *An. dthali* were mostly in overflow waters, stream bed pool and clean water without vegetation. Patton collected larvae of this species from wells and springs[43]. Adults of *An. dthali* are very sensitive to light and are often stimulated by flashlight. During the day, they rest in water storage tanks, storehouse, holes and mountain caves[44].

A total of 10 species of *Culex* were found in our investigation. *Cx. pipiens* is distributed in Europe, the middle part of North America, Africa, the some regions of Asia, Southern America, and Australia[45]. This species is distributed in the most parts of Iran[11]. In our study, *Cx. pipiens* was one of the most frequent Culicinae mosquitoes and collected from Mohr, Zarindasht and Lamerd. The monthly activity of this species in Mazandaran Province was started in the end of May and was increased in the beginning of July and decreased slowly in the mid of summer[46]. In our research, monthly activity of *Cx. pipiens* in Zarindasht began from June to September and in Mohr and Lamerd began from April to September. The study of seasonal activities of mosquitoes in the Belek region of Turkey showed that seasonal activity of *Cx. pipiens* increased from May to August and reached its peak in August[47]. This species breeds in pools, drainage canals, animal footprints, river side, hollows and lake shore[48]. *Cx. pipiens* was reported as a predominant species in Kashan County and preferred house ponds and sewage wells[19]. In the present study, this species was collected mainly (65%) in natural habitats (streams, stream bed pools, and springs) in comparison to artificial habitats. This is similar to the study of Azari-Hamidain[49]. In the present study, *Cx. pipiens* was one of the most abundant species which can be explained by the wide variety of the breeding places.

Cx. theileri is found in Palaearctic, Afrotropical and Oriental regions. *Cx. theileri* has been recorded in all provinces of Iran[11]. In our research, monthly activity of this species in Darab and Mohr began from April to September. In the study of Ferraguti *et al*., this species was collected from June and July[50]. The study of seasonal dynamics of mosquitoes in Turkey showed that *Cx. theileri* reached its peak in June and population density decreased during the period of July and August[51]. This finding is similar to the present study. This species was reported in a wide range of breeding sites in North-East of Iran[52]. In the study of ecology of mosquitoes in Western Iran, *Cx. theileri* preferred larval habitats without plants and stagnant, permanent and clean water[17]. This finding is identical with the present study. Zaim noted that it was mostly in natural habitats[53].

Cx. quinquefasciatus is reported from Fars, Bushehr, Hormozgan, Tehran, Kerman, Khuzestan, Sistan and Bluchestan[11,31]. In this study, it was recorded only from Khonj and the main peak was in June. This species was the most frequent mosquito collected from Khonj, with a total number of 474 specimens. *Cx. quinquefasciatus* larvae breed in the sewage system of the houses and could be a vector of microfilaria and West Nile virus[11,31,54]. In the study of ecology of mosquitoes in Chaco Province, larvae of this species were found mainly in artificial larval nests[55]. The study of mosquitoes in Nepal showed that *Cx. quinquefasciatus* reached its peak in July[56]. This finding is not similar to the present study. The monthly activities of this species in the state of Sao Paulo, Brazil were reported from April and September[57]. The study of mosquitoes in Argentina showed that high larval densities occurred in ditches and canals and were associated with the presence of vegetation[58].

Cx. tritaeniorhynchus is the main vector of Japanese encephalitis virus and restricted to the Palaearctic (Southern Asia), Afrotropical, and Oriental regions[12]. This species was the second most abundant species of *Culex* in Darab with a sum of 326 specimens (31%). This is different with the study of Azari-Hamidian who reported a different relative abundance of culicine mosquitoes in the Kerman area: *Cx. tritaeniorhynchus* (10.8%), *Cx. sinaiticus* (6.3%) and *Cx. theileri* (3.8%). Whereas *Cx. theileri* was more common than *Cx. tritaeniorhynchus* in the Darab region[59]. The study in Shadegan region, Southwestern Iran showed that *Cx. tritaeniorhynchus* is the one of the more common species in this area[60]. In the study of Ramesh *et al*., the main peak for this species was in July to September[61]. This agrees with our findings in Darab County. This species breeds in large or small bodies of clean and sunlit water, such as lakes, marshes and river edges[62]. Study in Guilan Province, showed that the species of *Cx. tritaeniorhynchus* preferred larval habitats with plants, transient, standing, clean water and with muddy bottoms[13].

Cx. perexiguus is recorded in the majority of provinces of Iran but it has never been reported from Fars and this record is new for the Fars mosquito fauna[11]. In our investigation, *Cx. perexiguus* collected from Khonj, Darab, Zarindasht and Lamerd. This species in Isfahan Province was reported from May to August, which is similar with our finding in Zarindasht[29]. In the study of Ammar *et al*., the main peak for this species was in July, and this agrees with our findings in Lamed and Zarindasht Counties[63]. This species reported in a wide range of breeding places such as stream ponds, seepages and irrigation ditches in the Cape Verde islands[64]. This agrees with our findings. *Cx. perexiguus* is the main vector of West Nile virus in Israel[65].

Cx. mimeticus is distributed in Fars, Azerbaijan, Guilan, Mazandaran, Kurdistan, Kerman, Luristan, Semnan, Khorasan, Isfahan, Chahar-Mahall, Yazd, Hormozgan, Zanjan, Kohkiluyeh, Bushehr and Khuzistan provinces[49,53]. Lotfi observed it in river bed pools and river edges[66]. *Cx. mimeticus* larvae were collected in July and August in Western Iran[14].

The Mediterranean thermophilic species *Cx. modestus* was reported in West and East Azerbaijan, Isfahan, Hormozgan and breeds in spring fed pools, rice fields and fresh or slightly saline water, in full sunlight with vegetation[53]. This species in central Europe was collected from April to September and reached its peak in July[67]. In the present study, *Cx. modestus* reached the highest density in August. *Cx. modestus* could be a vector of West Nile virus[68].

Cx. sinaiticus reported from Bushehr, Khuzestan, Sistan and Bluchestan, Fars, Kerman and Hormozgan provinces[11]. In the present study, it was one of the lowest population with a total of 7 specimens. This is in line with a study in Mahshahr District, Khuzestan Province that *Cx. sinaiticus* has the lowest population with a sum of 4 specimens[69]. Study in several years ago showed that *Cx. sinaiticus* preferred larval habitats with plants, muddy bottoms and stagnant, transient, clear water[53].

Oc. caspius has been collected from many provinces of Iran[11]. In this study, *Oc. caspius* was one of the lowest abundant species in Khonj region (0.7%). This is different from the study conducted by Navidpour, who showed that it was the most abundant species of Culicidae in the Shadegan wetlands, compromising 66.9% of the culicine population[60]. In this study, monthly activities of *Oc. caspius* was in June, August, but the monthly activities of this species in Isfahan Province was reported in July[29]. It was collected from Chisinau and Moldova, from June to August[70]. Study in West Azerbaijan showed the presence of West Nile virus in *Oc. caspius*[71].

Cs. longiareolata is recorded in all provinces of the country[12]. Moosa-Kazemi observed it in rice fields in Lenjan and Mobarakeh counties[18]. In this study, it was found in Darab and Mohr with a sum of 73 and 221 specimens, respectively. *Cs. longiareolata* was reported as the most abundant culicid species, in Kurdistan, Kermanshah and Sistan-Baluchistan provinces[15,17]. In the study of Aldemir and Boşgelmez, *Cs. longiareolata* larvae were collected from lush pasture, well, and canal and the main peak for this species was found in June and July[72]. The larvae are able to support a high level of contamination. They are filter feeder, but are too capable of predatory feeding, including cannibalism[73]. Adults rarely bite man, look to be ornithophilic, so this species appears to be of no medical importance[74].

Ae. vexans distributed in Oriental, Nearctic and Palearctic regions[75]. This species is reported from Kurdistan, Kermanshah, Mazandaran, Guilan, Azerbaijan and Hormozgan[17,53,76]. In this study, *Ae. vexans* collected from Darab from May to Agust. According to a new research, porcine reproductive and respiratory syndrome virus can be mechanically transmitted by *Ae. vexans*[77]. This species mainly feeds on mammals and could potentially serve as a bridge vector for West Nile virus[78]. *Ae. vexans* is a suitable host for dog heartworm (*D. immitis*)[79].

According to the present study, there are some potential vectors of medical and veterinary importance in Fars Province. Information about medically important mosquitoes can assist in control efforts and also present early warning signs for disease transmission venture. The occurrence of possibility of some arboviral diseases such as Japanese encephalitis and rift valley fever in Iran is remarkable. Thus, different aspects of their ecology such as active season and population dynamics need to be studied extensively.

Conflict of interest statement

We declare that we have no conflict of interest.

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