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Seasonal Larval and Adult Population Dynamics and Breeding Habitat Diversity of *Culex theileri* Theobald, 1903 (Diptera: Culicidae) in the Gölbaşı District, Ankara, Turkey*

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Abstract: In this research, which was carried out between August 1995 and July 1997 in an area that embraces Lakes Mogan and Eymir, Imrahor Valley and the Gölbaşı district of Ankara province, the seasonal larval and adult population dynamics, breeding habitat diversity and hibernation type of *Culex theileri* were studied and it was determined that 7 different habitat categories, such as marshes, lake shores, creek sides, pastures and animal footprints, can be breeding habitats for *Cx. theileri* and that it can be associated with 7 different mosquito species in these habitats. It was also established that larval and adult populations have seasonal fluctuations and that the hibernation period was spent by females in complete hibernation.

Key Words: *Culex theileri*, population dynamics, breeding habitats, hibernation

Ankara İli, Gölbaşı İlçesi'nde *Culex theileri* Theobald, 1903 (Diptera: Culicidae)'nin Mevsimsel Larva ve Ergin Populasyon Dinamizmi ve Üreme Habitatı Çeşitliliği

Özet: Bu araştırmada, Gölbaşı İlçesi, Mogan ve Eymir gölleri ve Imrahor Vadisi'ni kapsayan bölgede Ağustos 1995-Temmuz 1997 tarihleri arasında, *Culex theileri*'nin mevsimsel larva ve ergin populasyon dinamizmi, üreme habitatı çeşitliliği ve kışlama tipi araştırılmış ve *Cx. theileri*'nin yedi farklı kategorideki habitatı (Bataklık, göl kenarı, dere kenarı, mera, hayvan ayakizi gibi) üreme habitatı olarak kullanabildiği ve bu habitatlarda yedi farklı sivrisinek türü ile birlikte bulunduğu belirlenmiştir. Larva ve ergin populasyonlarının mevsimsel dalgalanmalar yaptığı ve kışlama döneminin tam hibernasyonlu dişiler ile geçirildiği saptanmıştır.

Anahtar Sözcükler: *Culex theileri*, populasyon dinamizmi, üreme habitatları, kışlama

Introduction

Mosquitoes serve as intermediate hosts in the transmission of 4 important human diseases: 1, malaria; 2, yellow fever; 3, dengue; and 4, filariasis (Belding, 1942). Especially in recent years, the distribution space of both mosquitoes and mosquito-borne diseases has been changing and expanding for reasons such as increasing rates of environmental corruption, climatic changes, vector and pathogen resistance to insecticides and drugs, progressive urbanisation and population movement (Gubber, 1988; Patz et al., 1996; Jetten and Focks, 1997). Therefore much research has been conducted, especially on vector and vector-suspected mosquitoes. *Culex theileri* does not seen to be involved in the transmission of any human diseases, but its importance as a vector has not been thoroughly studied. On the other hand, it was show that *Cx. theileri* is naturally infected by West Nile, Rift Valley fever, and Sindbis arboviruses, but only the transmission of the Sindbis arbovirus was demonstrated experimentally (Jupp et al., 1966; McIntosh et al., 1967; Harbach, 1988). Females of *Cx. theileri*, which are zoo-anthropophilic, feed mainly on mammals and are known to enter houses and bite human beings. They are widespread in the Mediterranean, Aegean, Marmara, Black Sea and Central

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Anatolian climatic regions (Parrish, 1959; Merdivenci, 1984; Harbach, 1988). As in other countries, mosquito control programmes are also implemented in Turkey. However, these programmes are generally not successful because they are not based on scientific studies. Accumulation of insecticides used excessively in large areas cause environmental problems. So it is beneficial to evaluate both the basic biological and ecological data before initiating any mosquito control programme (Alptekin and Kasap, 1996). In particular the determination of breeding habitats of mosquito populations and seasonal population dynamics make important contributions to the effectiveness of control programmes. This study was performed during August 1995-July 1997 in an area, which has a sensitive ecological balance with its hydrology, morphology, soil types, climatic characteristics and current biota. The purpose of this study was to determine the seasonal changes in the densities of larval and adult populations, habitat diversity and hibernation type of *Cx. theileri*.

Materials and Methods

The studies were carried out in an approximately 80 km^2 area (39º 48' N and 32º 48' E) including Lakes Mogan and Eymir in the Gölbaşı district of Ankara province (Figure 1). This area is important as it is the principal wetland of Ankara city and it has been documented as a natural conservation, tourism and recreational area. The area has the characteristics of a plain surrounded by highlands (895-1895 m) and it is quite rich in its aquatic ecosystem diversity, having the main aquatic ecosystems of the region within its borders; Lakes Mogan and Eymir, and Çökek and Gölbaşı swamps. In addition, other seasonal aquatic ecosystems are formed around Lake Mogan due to flooding during the spring. These wetlands are important breeding habitats of mosquito species in the region, for they are perennial during the mosquito breeding periods. Furthermore, essential breeding habitats exist around the shorelines of Lake Mogan since it is a eutrophic lake. There are several seasonal creeks in the area flowing into Lakes Mogan and Eymir which have the lowest elevation (Doğdu, 1990).

Determination of seasonal larval population density

Thirteen sampling quadrats in 7 different categories

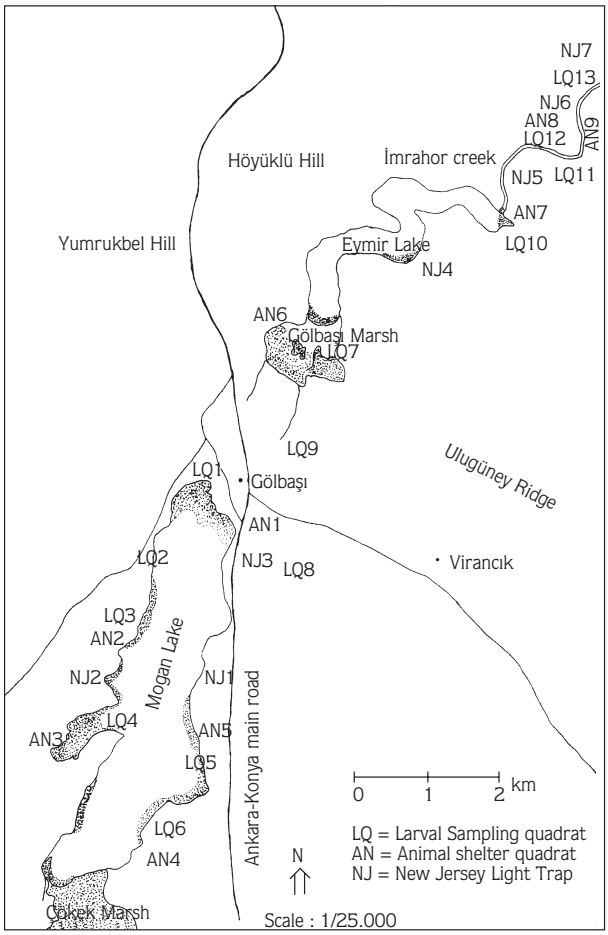

Figure 1. Map of study area showing the locations of larval sampling, animal shelter quadrats and New Jersey light traps.

were selected for the determination of the seasonal larval population density of *Cx. theileri*. The sampling quadrats were primarily selected to represent the general breeding habitats of the mosquitoes in the region and are long-lasting enough to make periodic (monthly) sampling possible (Figure 1, Table 1). In every sampling quadrat, 1-dip samples were taken randomly for every 1 m^2 on a monthly basis with a standard long-handled dipper (350 ml). Samples were always collected by the same individual at the same time in the morning (09:00-12:00) or afternoon (14:00-17:00). Every larva sample collected from each quadrat was put into a different pot and labelled before transportation to the Hacettepe University Ecological Sciences Research Laboratories (ESRL) (26 ± 2 ºC, 70 ± 5 %RH, 16:8 L:D). Third and fourth instar larvae were identified immediately in the laboratory, whereas first and second instars were allowed to develop

Table 1. Larvae sampling quadrats.

Sampling quadrats		Area (m^2)
1.	Lake Mogan edge marsh (LQ 1)	50
2.	Lake Mogan edge (LQ 2)	50
3.	Lake Mogan edge pasture (LQ 3)	100
4.	Lake Mogan edge marsh (LQ 4)	100
5.	Karaoğlan pasture animal footprints (LQ 5)	100
6.	Lake Mogan edge (LQ 6)	50
7.	Waste water purification pool (LQ 7)	50
8.	Canal (LQ 8)	100
9.	Canal (LQ 9)	100
10.	Lake Eymir edge (LQ 10)	100
11.	İmrahor Stream edge marsh (LQ 11)	100
12.	İmrahor Stream edge pasture (LQ 12)	100
13.	İmrahor Stream edge (LQ 13)	10

before identification. A specific number of larvae (20 larvae/quadrat) were reared to the adult stage; the associated larval and pupal exuviae were used for species identification. Identification was done using the keys (DuBose and Curtin, 1965; Harbach, 1985, 1988; Darsie and Samanidou, 1997). Finally, the number of larvae identified in every quadrat was recorded and seasonal larval population density was determined.

Determination of breeding habitats of *Cx. theileri*

During the studies, rural and urban areas in the region were examined and every habitat containing mosquito larvae was considered as a breeding habitat. Larval mosquito samples were collected within those breeding habitats and the breeding habitats of *Cx. theileri* were evaluated. Other mosquito species associated with those habitats were also determined.

Determination of seasonal adult population density

Light traps were used in the determination of adult population density. Seven New Jersey mosquito light traps (NJLTs) were set up in different places in the study area considering the most important breeding habitats of mosquitoes (Fiqure 1). Each light trap was run once a month between 19:00 and 07:00. Mosquitoes were kept in separate containers, which were labelled and sent to ESRL for identification and counting.

Determination of seasonal changes in gonotrophic status

Nine animal shelters were selected as female sampling quadrats in the study area (Figure 1). Sampling was performed in every animal shelter once a month by 2 collectors using an aspirator and torchlight on a 10 min basis. Samples were always taken by the same individuals at the same times (08:00-10:00). Samples collected were put into different containers, which were labelled and sent to ESRL.

Identifications of mosquito species collected from both light traps and animal shelters were made by using the keys (DuBose and Curtin, 1965; Harbach, 1985, 1988; Darsie and Samanidou, 1997). The gonotrophic status of female mosquitoes collected from animal shelters was determined according to Detinova (1962), and their numbers were recorded.

Data evaluation

The differences among all data were analysed (SPSS) for significance by one-way analysis of variance (ANOVA) (Zar, 1999).

Results

Seasonal larval population dynamics of *Cx. theileri*

Results obtained from the larval sampling quadrats are presented in Table 2. The presence of any significant difference among the sampling quadrats was investigated statistically using ANOVA. There is no significant difference among the 13 sampling quadrats ($p = 0.566$). Because of this similarity and the similarity in the seasonal fluctuations, seasonal larval population dynamics were determined by taking the averages of the numbers obtained monthly from the 13 sampling quadrats (Figure 2).

The larval population density was at its highest levels during August 1995-September 1995, and started to decrease in October 1995, reaching its lowest level in November 1995. Sampling studies continued during December 1995-April 1996, but no larva population was detected. Since no larvae were found during this season, it can be concluded that breeding activity had ended. Larvae sampling was reconducted in May 1996, and the larval population gradually increased, reaching a peak in September. With the end of the active breeding season, similar to the previous year, breeding activity stopped and

Table 2. Results from larvae sampling quadrats collected between August 1995 and July 1997.

Sampling Quadrats	Months/1995					Months/1996												Months/1997						
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
LQ 1	370	257	31	6	0	0	0	0	0	11	68	47	77	197	95	0	0	0	0	0	0	25	81	79
LQ 2	180	179	47	16	0	0	0	0	0	19	10	65	112	203	103	0	0	0	0	0	0	19	106	128
LQ 3	154	190	61	0	0	0	0	0	0	46	58	90	99	200	114	0	0	0	0	0	0	40	121	113
LQ 4	132	127	50	0	0	0	0	0	0	42	83	60	91	169	102	0	0	0	0	0	0	23	102	86
LQ 5	180	198	99	2	0	0	0	0	0	51	91	90	96	159	62	0	0	0	0	0	0	24	78	81
LQ 6	98	88	26	2	0	0	0	0	0	0	0	50	117	126	72	0	0	0	0	0	0	19	90	85
LQ 7	127	122	57	0	0	0	0	0	0	0	0	33	55	64	21	0	0	0	0	0	0	24	105	106
LQ 8	141	135	50	0	0	0	0	0	0	7	77	35	89	148	88	0	0	0	0	0	0	49	141	119
LQ 9	70	83	31	4	0	0	0	0	0	0	34	57	51	130	87	0	0	0	0	0	0	31	121	85
LQ 10	108	119	59	10	0	0	0	0	0	31	42	36	101	122	89	0	0	0	0	0	0	31	123	85
LQ 11	101	75	25	9	0	0	0	0	0	19	39	58	85	43	22	0	0	0	0	0	0	34	111	81
LQ 12	60	53	33	0	0	0	0	0	0	0	36	34	32	45	27	0	0	0	0	0	0	29	95	77
LQ 13	137	101	36	6	0	0	0	0	0	55	48	85	106	72	35	0	0	0	0	0	0	39	105	102

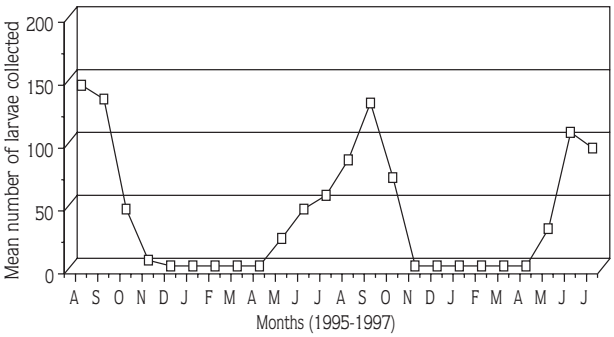

Figure 2. Seasonal changes in larval population density of *Cx. theileri* in the study area.

no larvae could be sampled during November 1996-April 1997 (Figure 2).

Breeding habitats of *Cx. theileri* and associated mosquito species

Breeding habitats in 12 different categories were distinguished throughout the study area for the purpose of determining *Cx. theileri*'s breeding habitats and associated mosquito species. Seven out of those 12 different breeding habitat categories contained *Cx. theileri* larvae. It was also observed that they can be found associated with other mosquito species in swamps, lake shores and pastures, which are large breeding habitats containing several sub-habitats. Yet they could not be found in habitats that are relatively smaller and man-made with extreme conditions such as drinking troughs, garden pools and cesspools (Table 3).

Table 3. Breeding habitats and associated mosquito species of *Cx. theileri*.

Larval Habitats	Mosquito species									
	Culex theileri	*Culex mimeticus*	*Culex pipiens*	*Culex perexiguus*	*Anopheles claviger*	*Anopheles maculipennis*	*Aedes caspius*	*Culiseta annulata*	*Culiseta longiareolata*	*Uranotaenia unguiculata*
Marsh	X	X	X			X	X			X
Lake shore	X	X	X	X		X				X
Creek side	X		X	X	X	X				
Canal	X		X	X						
Animal footprints	X		X	X	X	X	X			
Pasture	X	X		X	X	X	X			
Garden pool	*								X	
Waste water pool	X		X							
Cesspool	*		X							
Drinking trough	*		X					X		
Well	*		X		X					
Empty tins	*		X							

X = Found, * = Not found

Seasonal adult population dynamics and changes in the gonotrophic status of *Cx. theileri*

Sampling results obtained from 7 light traps and 9 animal shelters are shown in Tables 4 and 5. Analysis of any significant differences among the sampling results was performed separately for the light traps and animal shelters by using ANOVA. According to the results obtained these is no significant difference among the light traps ($p = 0.982$) or among the animal shelters ($p = 0.580$). Seasonal adult population dynamics were then determined separately for the light traps and the animal shelters by taking the averages numbers obtained monthly (Figures 3 and 4).

By the beginning of August (1995) the adult population density evaluated by light traps started to decrease gradually, and reached its lowest value in November (1995). By December no further adults could be sampled. This situation continued up to April (1996). Adults started to re-emerge in May (1996). Population density gradually increased after May (1996) and reached highest value in August (1996). Similar to the previous season, population density gradually decreased during September-November (1996) and no adult could be sampled between December (1996) and April (1997). Starting from May (1997), population density gradually increased again (Figure 3).

Unfed, fed, half gravid and gravid females were sampled in animal shelters in August and September 1995. It was seen that the population was gonotrophically active. However, only unfed females could be sampled between December 1995 and March 1996. This time it was determined that the population was gonotrophically inactive and unfed females were in complete hibernation. In May 1996, the sampling of fed, half gravid and gravid females could be performed again and the hibernation period was completed. Breeding activities continued between July and October 1996. The hibernation period started again in December 1996, as in the previous year, and only females in complete hibernation could be sampled (Figure 4).

Discussion

Collections of water, which provide breeding habitats for mosquito larvae, may be temporary or permanent, natural or man-made (Service, 1993). Breeding habitats of different mosquito species show great variation, but most species are specific to particular habitats (Alptekin and Kasap, 1997). The determination of breeding habitats is of great benefit to mosquito control methods. *Cx. theileri* is an adaptable species which utilises a wide range of breeding sites, but it is also a focal species, reaching high densities in some areas while appearing to rare or absent in others (Harbach, 1988). It was determined that *Cx. theileri* is associated with 7 other species in 7 different breeding habitats out of the 12 in the study area. Alten and Boşgelmez (1996) previously determined 5 different breeding habitats of *Cx. theileri* out of 19 in their study area, which included the Ortaca and Dalaman districts of Muğla province. In another study, carried out by Margalit et al. (1988) in Israel, *Cx. theileri* was observed to be the most widespread species in several habitats associated with 6 different species. When the active breeding habitats of *Cx. theileri* in the study area were examined, it was determined that the

Table 4. Number of females trapped in NJLTs between August 1995 and July 1997.

Light traps	Months/1995					Months/1996												Months/1997						
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
LT 1	53	42	18	6	0	0	0	0	0	32	38	34	91	52	23	9	0	0	0	0	0	7	27	42
LT 2	54	44	19	9	0	0	0	0	0	41	58	67	73	38	21	6	0	0	0	0	0	10	50	53
LT 3	48	37	10	2	0	0	0	0	0	33	45	46	91	56	24	7	0	0	0	0	0	26	57	64
LT 4	53	38	26	0	0	0	0	0	0	33	31	52	76	48	33	7	0	0	0	0	0	19	38	51
LT 5	48	30	14	2	0	0	0	0	0	22	39	47	61	36	23	6	0	0	0	0	0	13	24	47
LT 6	46	22	8	0	0	0	0	0	0	30	39	60	80	48	28	9	0	0	0	0	0	19	43	57
LT 7	46	21	12	5	0	0	0	0	0	31	46	51	89	21	20	4	0	0	0	0	0	13	45	35

Table 5. Number of females collected from animal shelters between August 1995 and July 1997 (G = Gravid, HG = Half gravid, F = Fed, UF = Unfed).

Animal shelters	Gono-trophic Status	Months																						
		1995					1996												1997					
		A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
AS 1	G	0	0	0	0	0	0	0	0	0	0	7	8	11	7	10	1	0	0	0	0	0	0	9	22
	HG	0	0	0	0	0	0	0	0	0	1	16	15	40	15	30	8	0	0	0	0	0	3	35	24
	F	0	0	0	0	0	0	0	0	0	10	17	26	28	38	30	20	0	0	0	0	0	7	16	10
	UF	0	0	0	0	0	0	0	9	7	7	5	5	4	6	22	23	36	25	23	10	9	5	10	8
AS 2	G	36	11	0	0	0	0	0	0	0	4	7	10	12	6	15	0	0	0	0	0	0	5	11	15
	HG	52	26	0	0	0	0	0	0	0	9	17	11	18	12	31	1	0	0	0	0	0	11	22	37
	F	31	19	10	0	0	0	0	0	0	11	24	27	31	19	22	3	0	0	0	0	0	5	24	7
	UF	18	8	18	16	9	9	11	6	7	3	9	12	8	9	16	32	23	27	20	12	9	2	9	10
AS 3	G	21	23	0	0	0	0	0	0	0	8	8	24	26	15	9	0	0	0	0	0	0	3	4	21
	HG	87	50	6	0	0	0	0	0	0	7	8	12	15	56	26	2	0	0	0	0	0	9	20	44
	F	17	16	10	5	0	0	0	0	0	12	19	29	36	11	28	7	0	0	0	0	0	6	9	3
	UF	11	12	26	19	8	8	12	9	9	5	6	12	8	8	9	24	28	27	18	8	10	2	6	9
AS 4	G	14	9	0	0	0	0	0	0	0	7	9	29	14	6	3	0	0	0	0	0	0	3	11	17
	HG	31	21	1	0	0	0	0	0	0	3	9	18	10	10	9	1	0	0	0	0	0	8	20	59
	F	18	12	5	3	0	0	0	0	0	12	22	41	33	17	18	5	0	0	0	0	0	5	13	28
	UF	12	4	17	18	9	9	9	12	9	7	9	3	6	8	7	22	24	23	19	13	8	1	7	9
AS 5	G	11	6	0	0	0	0	0	0	0	5	9	7	16	9	3	0	0	0	0	0	0	1	15	8
	HG	14	9	3	0	0	0	0	0	0	10	12	15	15	9	9	0	0	0	0	0	0	9	28	21
	F	16	14	6	0	0	0	0	0	1	13	24	25	20	14	13	8	0	0	0	0	0	7	11	10
	UF	17	32	15	5	6	9	11	13	8	4	6	9	16	12	6	25	22	14	14	10	11	1	8	4
AS 6	G	26	29	0	0	0	0	0	0	0	8	11	26	11	15	9	0	0	0	0	0	0	1	12	22
	HG	63	20	3	0	0	0	0	0	2	13	22	20	18	25	18	1	0	0	0	0	0	10	30	42
	F	11	14	11	0	0	0	0	0	3	16	32	22	18	28	27	4	0	0	0	0	0	3	14	12
	UF	22	10	14	10	3	7	6	8	8	3	11	6	10	9	16	18	29	17	14	12	10	1	8	6
AS 7	G	11	7	0	0	0	0	0	0	0	9	11	13	7	3	8	0	0	0	0	0	0	5	17	12
	HG	17	13	7	0	0	0	0	0	1	4	18	13	12	14	12	0	0	0	0	0	0	7	34	19
	F	11	21	13	3	0	0	0	0	2	13	36	24	17	23	26	1	0	0	0	0	0	3	16	7
	UF	9	16	17	3	0	6	4	6	9	8	12	13	9	13	13	23	24	16	17	13	8	0	6	10
AS 8	G	9	13	0	0	0	0	0	0	1	9	9	22	10	5	6	0	0	0	0	0	0	2	12	10
	HG	10	8	2	0	0	0	0	0	1	6	4	34	16	6	15	0	0	0	0	0	0	7	13	47
	F	18	32	10	0	0	0	0	0	7	22	24	28	14	24	24	3	0	0	0	0	0	3	22	23
	UF	8	13	6	6	4	6	7	10	12	6	6	10	17	6	6	15	17	12	11	12	8	0	11	10
AS 9	G	10	19	0	0	0	0	0	0	2	6	6	7	12	5	6	0	0	0	0	0	0	5	6	14
	HG	17	14	6	0	0	0	0	0	4	7	10	16	11	5	16	2	0	0	0	0	0	7	19	19
	F	16	6	6	0	0	0	0	0	3	8	10	12	19	13	13	3	0	0	0	0	0	3	10	14
	UF	12	8	9	1	1	5	1	10	7	8	4	5	9	7	6	18	25	19	8	11	8	0	10	6

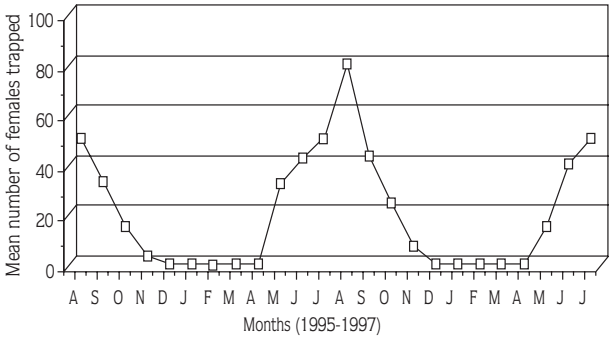

Figure 3. Seasonal changes in females population density of *Cx. theileri* trapped by NJLTs.

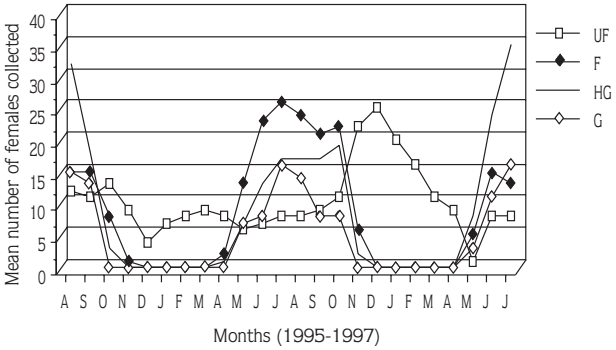

Figure 4. Seasonal changes in gonotrophic status of females *Cx. theileri* in animal shelters (UF = Unfed, F = Fed, HG = Half gravid, G = Gravid).

species prefer natural and large habitats, which are generally present in rural regions, such as marshes, lake shores, creek sides and pastures, and some man-made and small habitats, which are generally peculiar to urban areas, such as wells, cesspools and garden pools. According to Alten and Boşgelmez (1996), pastures are the most important breeding habitat of this species.

At the end of sampling studies, which were conducted in the study area between August 1995 and July 1997 to determine seasonal larval population dynamics of *Cx. theileri*, it was established that larval population dynamics are subject to seasonal fluctuations. It is known that mosquitoes are greatly affected by climatic changes. While *Cx. theileri* larvae could be sampled in every sampling quadrat between May and October, they could not be found between December and April. This indicates that the active breeding period is between May and October and the hibernation period is between December and April.

Results obtained from animal shelters and light traps are in agreement with the larval population dynamics. Although females were caught in light traps between May and November, they could not be trapped between December and April. The absence of females shows that they hibernate and stay in winter hibernation sites during these months. On the other hand, females, which have a different gonotrophic status, could be collected from animal shelters in all months of the year. The increase in the density of females that are unfed and in complete hibernation in animal shelters during the hibernation period shows parallelism with the results obtained from the larval sampling quadrats. The decrease in the density of unfed females with an increase in the density of fed, half gravid and gravid females indicates the ending of the hibernation period and the beginning of an active breeding period. Similarly, females could be trapped in light traps for the first time in May and the density of females increased during the active breeding period. Consequently, it was determined that larval and adult populations fluctuate seasonally due to climatic conditions and females spend the periods of unsuitable climatic conditions in safe place such as animal shelters.

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