Online ISSN: 2299-9884
Polish Journal of Entomology 90(1): 14–26 (2021)
DOI: 10.5604/01.3001.0014.8065

Mosquito survey reveals the first record of *Aedes* (Diptera: Culicidae) species in urban area, Annaba district, Northeastern Algeria

Djamel Eddine Rachid Arroussi[1*], Ali Bouaziz[2], Hamid Boudjelida[1]

[1] Laboratory of Applied Animal Biology, Department of Biology, Faculty of Sciences, University Badji Mokhtar Annaba, Algeria.

[2] Department of Biology, Faculty of Nature and Life Sciences, Mohamed Cherif Messaadia University Souk Ahras, Algeria.

* Correspondending author: arroussi.rachid@yahoo.fr

Abstract: The diversity, distribution and ecology of mosquitoes, especially arbovirus vectors are important indices for arthropod-borne diseases control. The mosquito larvae were collected in different habitats in four sites of Annaba district, Algeria, during the period of March 2018 to February 2019 and the properties of larval habitats were recorded for each site. The systematic study revealed the presence of 8 species belonging to 4 genera; including *Culex pipiens* (Linnaeus, 1758), *Culex modestus* (Ficalbi, 1889), *Culex theileri* (Theobald, 1903), *Culiseta longiareolata* (Macquart, 1838), *Anopheles labranchiae* (Falleroni, 1926), *Anopheles claviger* (Meigen, 1804), *Aedes aegypti* (Linnaeus, 1762) and *Aedes albopictus* (Skuse, 1894). Among the species, *C. pipiens* presented the highest species abundance (RA %) (55.23%) followed by *C. longiareolata* (20.21%). The *Aedes* species are recorded for the first time in the study urban area. Variation of diversity in different sites depends on the type of breeding habitat. These results provided important information on species diversity, distribution and factors associated with breeding habitats. They could be used for the mosquito control and to prevent the spread of mosquito-borne diseases to the population of the region.

Key words: Culicidae, *Aedes*, *Culiseta*, systematics, biodiversity

Introduction

Diseases transmitted by hematophagous arthropods represent a threat for animal and human health with the increase of their emergence outside the endemic areas. Mosquitoes (Diptera: Culicidae) are considered as the main vectors of pathogens of various important diseases such as malaria, filariasis, dengue fever, yellow fever, chikungunya, West Nile virus, Zika virus and other arboviruses responsible for encephalitis, bacteriosis, and helminthiasis, which are today among the greatest health problems in the world (Fontenille *et al.* 1995, Amraoui *et al.* 2019). Many arboviruses have been isolated from mosquito species belonging to the genera *Culex*, *Aedes* and *Culiseta* (Scott & Weaver 1989, Pfeffer & Dobler 2010). West Nile virus (WNV), which is worldwide distributed, is maintained in an enzootic cycle with birds that serve as amplification reservoir hosts and mosquitoes as the principal transmitting vectors. Humans and animals are considered dead-end hosts because they do not produce frequently enough sufficient viremia to infect mosquitoes (Campbell *et al.* 2002, Hayes *et al.* 2005). Since the WNV appeared in Europe (Boukraa *et al.* 2016), the introduction of the disease in the North Africa by infected migratory birds arriving from Europe is probable. Mosquitoes in the genus *Culex* have been widely implicated as primary vectors of WNV, since it has been detected largely as ornithophilic mosquitoes, especially *Culex pipiens* (Linnaeus, 1758), *Culex modestus* (Ficalbi, 1889), *Culex torrentium* (Martini, 1925) (Calistri *et al.* 2010), *Anopheles maculipennis* (Meigen, 1818) (Engler et al. 2013) and *Aedes albopictus* (Skuse, 1894; Pfeffer & Dobler 2010).

Aedes aegypti (Linnaeus, 1762) and *A. albopictus* mosquitoes are aggressive invaders of anthropogenic environments capable of spreading. In Europe, A. *albopictus* was first detected in Albania in 1979 (Adhami & Reiter 1998) and it became quickly well established in all Mediterranean countries of the continent (Akiner *et al.* 2016). In Africa, these species were reported firstly in the early 1990s in South Africa and Nigeria (Cornel 1991). Thereafter, it was described in several West and Central African countries (Savage *et al.* 1992). In North Africa, It was detected for the first time in Algeria in 2014 (Izri *et al.* 2011, Benallal *et al.* 2016), in Morocco in 2015 (Bennouna *et al*. 2017) and in Tunisia in 2018 (Bouattour *et al.* 2019). Despite having a different biogeographical origin, with *A. aegypti* originating from Africa and *A. albopictus* from Asia (Kelly *et al.* 2019), these mosquitoes have converged on a similar ecology, ovipositing in man-made water containers. *A. aegypti* is an urban mosquito feeding exclusively on humans. On the other hand, *A. albopictus* colonizes a larger range of sites and feeds on both animals and humans (Delatte *et al.* 2010).

Environment, climate change, human activities, as well as intensification of international trade enhance vector population densities consequently allows the reemergence of mosquito-borne disease (Gould & Higgs 2009). The development period from egg to adult varies among species and is strongly influenced mainly by ambient temperature. Mosquitoes larvae live in a wide variety of natural and artificial habitats, such as temporary and permanent water resources, unclean and clean water and stagnant or stream waters (Hanafi-Bojd *et al.* 2012). Adult mosquitoes are very diverse in host searching, biting behaviour, dispersal and reproductive strategies (Blaustein & Chase 2007). The interaction of biotic and abiotic factors; contain adult sugar and blood meal types and the physicochemical parameters of larval habitats, affects significantly the mosquito ecological adaptability and vectorial capacity for disease transmission with significant concepts for vector management and control (Juliano 2009, Boukraa *et al.* 2016). Accordingly, investigating biotic and abiotic factors for various mosquito fauna make it easier to monitor potential modifications of larval habitats affected by rains, global climate change and man-made activities (Juliano 2009, Boukraa *et al.* 2016).

Over the last two decades, several studies in Algeria have been dealing with the culicidal fauna. A large number of them have focused on systematic, biochemistry, physiology, and new alternative products for mosquito control. (Boudjelida *et al.* 2005, Boudemagh *et al.* 2013, Bouaziz *et al.* 2017, Aïssaoui & Boudjelida 2017, Amira *et al.* 2018, Djeghader *et al.* 2019). Considering the fact that in the Annaba region, some vector mosquitoes of diseases, such as West Nile virus, filariasis and malaria are recorded (Fontenille & Harrat 2010), the study on the composition, distribution and ecology of mosquito species is very important of vector control programs and monitoring strategies of disease vectors, such as *Culex* and *Aedes* species. Also such survey prevents of the vectors from spreading and establishment in the area and avoids the risk of disease transmission, since a potential disease clusters are present due to human immigration from South to North. The aim of this investigation was to estimate the composition, distribution and some ecological aspects of mosquitoes in Annaba district, with emphasis on arbovirus vectors, *Aedes* species.

Material and Methods

Study sites

The study was carried out in four locations, Annaba, Sidi Amar, Berrahal and Treat, situated in The North-East of Algeria, belonging to Annaba district (36°54′59.146′′N, 7°46′7.044′′E) (Fig. 1). This area is characterized by a Mediterranean climate, soft in winter, hot, and humid in summer. The annual rainfall varies between 650 and 1 000 mm. The average relative humidity changes from 40% to 80%. The averages of the

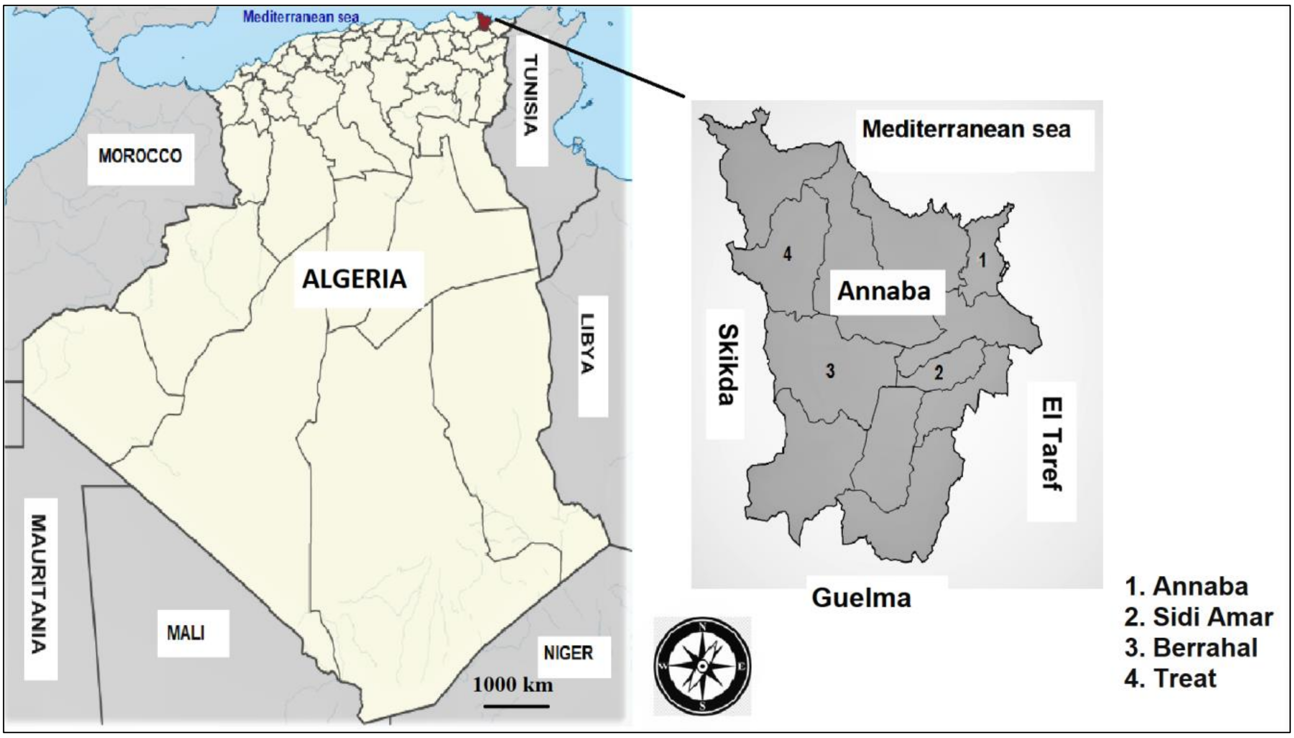

Fig. 1. Map of Algeria and locations of study sites in Annaba district, Algeria.

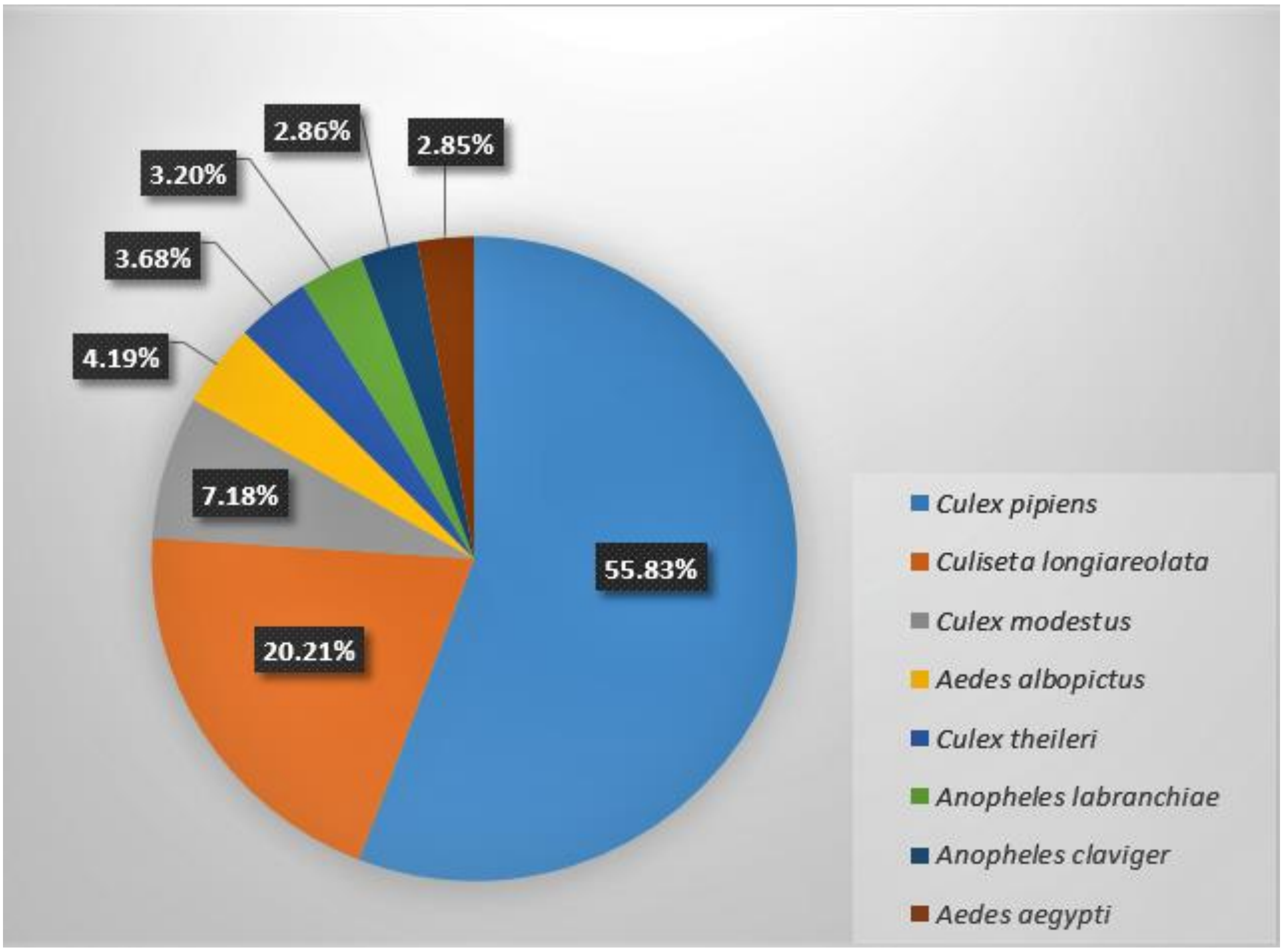

Fig. 2. Diversity and relative abundance (RA %) of mosquito species recoded in the study area (March 2018 to February 2019).

maximum and minimum temperatures are 31.4°C and 10.1°C, respectively. Weather data (precipitation and temperature) were obtained from local meteorological station.

Mosquito larval habitat characteristics

The ecological characteristics of mosquitoes larvae containing properties of collecting habitats (urban, peri-urban), type (artificial/natural), water state (stagnant, stream, seepage and water container), water appearance water (turbid and clear) and exposure to day-light (full, partial sun light and covered or shaded), were considered. The temperature and pH of the water habitats were measured and recorded directly, in the field using a Multi-parameters analyzer (Hanna HI. 9125). These were happened during the hot period of the day, in the afternoon between 13:00 and 16:00.

Mosquito larvae collection

All sites have been investigated 2 times per month, from March 2018 to February 2019. Larvae were collected by using the dipper method made-up by a plastic pan (500 ml). The collection was done in several places of breeding sites to obtain homogeneous samples (8–12 times). The samples of the same breeding sites are mixed and placed in individual plastic containers and labeled. Once in the laboratory, all larvae and pupae were counted and the immature stages were separated to the different larval stages and reared. After, the breeding jars of older stages and pupae of each sample were placed in emerging boxes (25×25×30)cm in order to obtain adults (males in particular) that were required to confirm identification by analyzing of the genitalia of some species. The younger larvae were reared in boxes, in order to collect gradually the fourth stage larvae. These were preserved in 75% ethanol in small flasks (50 ml) and labeled with date, study site, number and code of the breeding site.

Morphological identification

The identification of mosquito species was made according the morphological parameters described previously (Schaffner *et al.* 2001, Himmi *et al.* 1995). In the laboratory, the larvae of the fourth stages and the male adult genitalia were dissected using a stereo-microscope (20–40 × magnification), mounted between slide and cover slip and examined under a microscope (100–400 × magnification). The different parts of the insect were separated; head, thorax and abdomen extremity, where the main criteria of identification are located. Whereas some species there genitalia should to be examined in order to be identify. Sampled mosquito species identification was based on morpho-taxonomy analysis, using the electronic identification keys (Brunhes *et al.* 1999, Brunhes *et al.* 2001). Regarding the *Aedes* species and their recent appearance in urban areas, the new classification suggested by Wilkerson *et al*. (Wilkerson *et al.* 2015) was used, with the maintain of the traditional genera names.

Data Analyses

Several indices were used to study the mosquito populations, collected from the different study sites of the area.

The dominance of the mosquito species for each site was calculated by the relative abundance (RA %). This was expressed by the ratio between number of specimens of a species and the total number of specimens of all mosquito species collected in the site × 100.

Shannon diversity index (H'), is the amount of information provided by a sample on the structures of the stand from which the sample comes and on the way individuals are distributed among various species (Daget 1976). It is calculated as follows: $H' = - \Sigma\ Pi\ Log2\ Pi$ where: $Pi = ni/N$ (Hence: H’: Specific diversity, ni: Number of species, N: Total stand size). A high value of this index corresponds to

Table 1. Characteristics of mosquito larval collection sites in Annaba district during the study period (March 2018 to February 2019).

Site name	Number of sites	Habitat types	T °C	pH
Annaba	6	Urban: Open, permanent, stagnant water and clean	18.9 ± 3.31	7.5 ± 0.27
	15	Urban: Cover, permanent, stagnant and wastewater	24.9 ± 2.64	8.4 ± 0.29
Sidi Amar	4	Urban: Open, permanent, stagnant, clean	20.0 ± 3.50	7.6 ± 0.3
	8	Urban: Cover, permanent, stagnant, wastewater	25.8 ± 2.66	8.6 ± 0.54
Berrahal	4	Peri-urban: Open, permanent, stagnant, clean	19.8 ± 2.90	7.5 ± 0.34
Treat	3	Peri-urban: Open, permanent, stagnant, clean	19.6 ± 3.67	7.7 ± 0.55

Table 2.Diversity of Culicidae species in Annaba district, during the study period (March 2018 to February 2019).

Family	Subfamily	Genera	Species
Culicidae	Culicinae	*Culex*	*Culex pipiens* Linneaus, 1758 *Culex theileri* Theobald, 1903 *Culex modestus* Ficalbi, 1890
		Culiseta	*Culiseta longiareolata* Maquart, 1828
		Aedes	*Aedes albopictus* Skuse, 1894 *Aedes aegypti* Linnaeus, 1762
	Anophelinae	*Anopheles*	*Anopheles labranchiae* Falleroni, 1926 *Anopheles claviger* Meigen, 1804

Table 3. Spatial distribution of diversity indexes and the dominance of mosquito species recorded in the study area during the study period (March 2018 to February 2019). H': Shannon index, E: Equitability, RA: Relative Abundance (%).

Site	*H'*	*E*	Species abundance (RA%)
Annaba	1.58	0.79	*C. pipiens* (51.62%), *C. longiareolata* (33.15%), *A. albopictus* (9.20%), *A. aegypti* (6.04%)
Sidi Amar	1.35	0.67	*C. pipiens* (66.52%), *C. longiareolata* (21.66%), *A. albopictus* (6.88%), *A. aegypti* (4.93%)
Berrahal	1.72	0.66	*C. pipiens* (64.49%), *C. theileri* (6.57%), *C. modestus* (12.40%), *C. longiareolata* (6.11%), *A. labranchiae* (5.30%), *A. claviger* (5.13%)
Treat	2.40	0.93	*C. pipiens* (27.45%), *C. theileri* (9.89%), *C. modestus* (20.19%), *C. longiareolata* (25.32%), *A. labranchiae* (9.50%), *A. claviger* (7.65%)

a species-rich stand with a balanced distribution of abundance. Conversly, the low distribution value corresponds either to a stand, charadterized by a low number of species for a high number of individuals, or to a stand in which there is a dominant species.

In order to estimate the distribution of mosquito population and to compare stand structures in the study sites the Equitability (E) was calculated (Ramade 1984). It is the relationship between specific diversity (H') and maximum diversity (Hmax) and is expressed as the following formula: $E = H' / Hmax$ with $H'max = Log2\ S$ (S: is the specific richness of species and was estimated by the total number of each species per site (Spellerberg & Fedor 2003).

Results

Composition of Culicidae fauna in the study region

In the present survey, different sampling sites were divided geographically in two types, urban and peri-urban sites and some ecological characteristics of the breeding habitats were considered (Table 1). Two types of the breeding habitats in the urban site were recorded, covered ones have stagnant wastewater and seepage and the open ones made of clean stagnant water. The peri-urban habitats had turbid water with muddy substrate and shallow depth. It was observed

Table 4. Temporal distribution of mosquito species recorded at study sites during the study period (March 2018 to February 2019).

Species	Season											
	Spring			Summer			Autumn			Winter		
	Month											
	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II
C. pipiens	+	+	+	+	+	+	+	+	+	+	+	+
C. theileri	-	+	+	+	+	+	+	-	-	-	-	-
C. modestus	-	-	+	+	+	+	+	+	-	-	-	-
C. longiareolata	+	+	+	+	+	+	+	+	+	+	+	+
A. labranchiae	-	+	+	+	+	+	-	-	-	-	-	-
A. claviger	+	+	+	+	+	+	-	-	-	-	-	-
A. albopictus	-	-	+	+	+	+	+	+	-	-	-	-
A. aegypti	-	-	+	+	+	+	+	+	-	-	-	-
Total of species	3	4	8	8	8	8	4	4	2	2	2	2

Table 5. The average of the temperature (°C) and the rainfall (mm) of Annaba district during the study period (March 2018 to February 2019).

Month	Season	Year	T max. (°C)	T min. (°C)	Rainfall (mm)
March	Spring	2018	19.6	13.5	57
April			20.3	17.2	68
May			23.0	17.9	53
June	Summer	2018	27.6	22.1	5
July			31.4	25.9	0
August			30.4	25.5	66
September	Autumn	2018	29.8	24.6	63
October			24.0	21.3	65
November			21.6	15.3	61
December	Winter	2019	18.3	12.6	33
January			14.7	10.3	101
February			16.0	10.1	85

that all these species exploit differently the habitats. A total of 5 127 mosquito larvae collected reveals the presence of 8 species, belonging to 4 genera, distributed into two sub-families. The first is the Culicinae and is represented by 3 genera; *Culex, Culiseta,* and *Aedes*. The second one is Anophelinae with a single genus the *Anopheles* (Table 1). Out of these genera, genus *Culex* was found to be the predominant taxa, with record of 3 species; *Culex pipiens, Culex theileri* (Theobald, 1903), and *Culex modestus*. *Culiseta* followed this with one species, *Culiseta longiareolata* (Macquart, 1838).The two genera, *Anopheles* and *Aedes*, were both represented by two species, *Anopheles labranchiae* (Falleroni, 1926), *Anopheles claviger* (Meigen, 1804) and *A. aegypti* and *A. albopictus* respectively (Table 2). The most abundance species was *C. pipie*ns 55.83% followed by *C. longiareolata* 20.21% (Figure 2). Other collected mosquito species were *Culex modestus* and *C. theileri* with 7.18 and 3.68% respectively. The abundance of *A. labranchiae* was 3.20% and *A. claviger* with 2.86%. The *Aedes* species recorded for the first time in this area were *A. albopictus* with 4.19% and *A. aegysti* with 2.85% of abundance (Fig. 2).

The dominance of the mosquito species for each site was estimated by the relative abundance (RA %) and is presented in Table 3. The results showed that *C. pipiens* and *C. longiareolata* were the most abundant and dominant species recorded in all sites. *C. pipiens* and *C. longiareolata* respectively, had the most distribution and adaptation to different types of larval habitats. These two species were found in cover larval habitat, situated in urban and peri-urban sites and are permanent with stagnant wastewater. In contrast, *C. theileri, C. modestus*, *A. labranchiae*and *A. claviger,* were found only in peri-urban in stream, stagnant and clean or turbid water with muddy substrate that was exposed to sunlight. The distribution of *A. albopictus* and *A. aegypti* was observed mostly in larval small habitats like jars, used tires and containers, with clean water and they were covered with different types of plants (Table 1).

The distribution of species presents a correlation with the vegetation in the breeding habitats. While the maximum species density was observed in a temperature ranging from 20 to 27.7°C and an alkaline medium with a pH varies 8 to 9. In the present study, the temperature and pH of the breeding waters are ranging between 18.9±3.31°C to 24.9±2.64°C and 7.5±0.27 to 8.6±0.54 respectively (Table 1).

There were differences in the species diversity, as indicated by the values of Simpson's diversity index, Shannon-Weaver index (H'), the Equitabitity (E) and the Relative Abundance (RA%) of the mosquito fauna in the study sites of Annaba district (Table 3). The two indices were found to be maximal in Treat site (H': 2.40 and E: 0.93), whereas the estimated diversity (H': 1.35) and Equitability (E: 0.66) were the lowest in Sidi Amar site.

Temporal distribution according to seasons

The study was conducted over four seasons where two species, *C. pipiens* and *C. longiareolata* were mainly present throughout the year (Table 4). While during the warm period that begins at the last month of the spring season and extends to the end of the autumn season, all species inventoried in the study area were found to be omnipresent. Finally, during the rainy season, there was a fairly remarkable decrease in the identified number species and this is in correlation with the decrease in temperature during the same period.

The results show that temperature and rainfall are influencing the density and the distribution of mosquito. The average of the maximum temperatures during the period study were varying between 31.4°C and 25.9°C in hot period; the summer and 14.7°C and 10.3°C in the cold period the winter (Table 5). During the winter and the spring seasons, a fluctuation in temperatures is recoded with the absence of some species (Table 3). The mosquito distribution and increase the abundance were recorded with high temperatures mainly during the hot summer and autumn (Table 4). In the study area between 5 mm and 101 mm of rainfall were recorded and this supply the breeding habitats with water.

Discussion

The geographical position, by the Mediterranean Sea, Annaba agglomeration represents a touristic pole. The presence and the large distribution of mosquitoes in this region represent a serious society problem because of their nuisance and considered as a potential pathogen vectors. Mosquito monitoring becomes imperative for the control.

Our systematic investigation showed the presence of 8 species belonging to 4 genera; *Culex, Culiseta, Aedes* and A*nopheles*. The *Culex* genus is essentially composed *C. pipiens*, found in urban and peri-urban areas, and with a modest degree *C. modestus* and *C. theileri*. The *Culiseta* genus was present with one species, *C. longiareolata.* The two genera, *Anopheles* and *Aedes*, were both recorded by two species, *A. labranchiae, A. claviger*and *A. aegypti* and *A. albopictus,* respectively. Previous studies of Algerian Culicidae, based on literature data, reported the presence of 48 species (Brunhes *et al.* 2000). Since a new species were identified and added to the Algerian mosquito fauna; *A. gambiae* and *C. quinquefasciatus* (Boubidi *et al.* 2010), the tiger mosquito *A. albopictus*, and *C. territans* (Izri *et al.* 2011, Lafri *et al.* 2014). A survey, in a rural habitat, situated in the extreme northeast of the country, revealed the presence of 13 mosquito species, belonging to 5 genera (Amara Korba *et al.* 2015). In the North center of Algeria, 27 species of Culicidae were listed in the region of Algiers (Senevet & Andarelli 1963, Senevet & Andarelli 1966). While in the West side of the country a number of 20 species of Culicidae were noted (Senevet & Andarelli 1963). The inside part of the country, the inventory of mosquitoes revealed the presence of 12 and 7 species, in Mila (Senevet & Andarelli 1966, Hassain 2002) and Constantine (Messai *et al.* 2011) respectively and it was indicated that the *Culex* species was the dominant. In a semi-arid region, Tebessa, a culicidal study revealed the presence of 10 species belonging to 3 genera; *Culex, Culiseta* and *Aedes* (Aïssaoui & Boudjelida 2017). Similar studies were done in the Northern region of Aures, 4 species of *Culex* (*C. mimeticus, C. hortensis, C. laticinctus* and *C. pipiens*), 3 species of *Anopheles*; (*A. labranchiae, A. hispaniola*, and *A. marteri*) and a single species of *Culiseta*; *C. longiareolata,* were recorded (Senevet & Andarelli 1960), with absence of the genus of *Aedes*.

The distribution and the density of mosquito species were inconstant, during the sampling methods. The difference in the mosquito density in the study sites was probably due to the phenology of species during the study period and the biotopes and climatic conditions, which play the role of limiting factor for much insect proliferation. Different in number species, is the result of the sampling methods, differences between environmental location, mosquito habitat types, the duration of the study and the further appearance of new artificial mosquito breeding habitats, surging from the large building construction activity (Alahmed *et al.* 2011).

Understanding mosquito species composition would reflect the presence of different potential mosquito vectors in this environment. From the recorded mosquito community, species can be identified as potential vectors of pathogens. Species from the genera *Culex* and *Aedes* are known to transmit pathogens (Becker *et al.* 2010). *C. pipiens* was trapped in large numbers in all sites and most of the habitats. *C. pipiens* is a known as a potential vector for WNV disease, which already circulates in many parts of Africa (Han *et al.* 1996, Turell *et al.* 2005). The tiger mosquito *A. albopictus* shows an explosive distribution even in the urban sites and represents a vector of some arboviruses, including WNV, dengue, chikungunya and possibly Zika (Aliota *et al.* 2016, Petrić *et al.* 2014, Chouin-Carneiro *et al.* 2016).

The presence of *Culex, Aedes* and *Anopheles* mosquito species, in this area, will expose the population to a risk of mosquito-borne diseases; including malaria, filariasis, and arboviruses. Algeria was an endemic malaria country and major epidemic in the north of the country were attributed to *Plasmodium vivax* (Hammadi *et al.* 2009). The main factor contributing to the resurgence and the spread of malaria is the infected people movement from endemic areas to another where mosquito vectors are present despite of the disease has been eradicated (Martens & Hall 2000).

The spatio-temporal results showed that the *C. pipiens* and *C. longiareolata* were distributed over the all year and this concord with a previous work (Aïssaoui & Boudjelida 2017). This fact could be explained by the global warming translated into North Africa by a soft winter (Izri *et al.* 2011). The ecological analysis of the results such as the relative abundance reveals that *C. pipiens* was the most distributed species followed by *C. longiareolata*. It was reported that *C. pipiens* and *C. longiareolata* species were very widely distributed at the Mediterranean African countries, (Himmi *et al.* 1995). Previous works, reporting the abundance and the dominance of these two species (Wilkerson *et al.* 2015, Spellerberg & Fedor 2003), confirmed this. The spatio-temporal distribution of *A. aegypti* and

A. albopictus presents a correlation with the vegetation in the breading habitats, constituting an organic matter essential to the development of the immature stages. Some parameters had been represented to show the global scale association between climatic factors and development, potential distribution and population dynamics of *Aedes* mosquitoes (Senevet & Andarelli 1966). While the maximum species density was observed in a temperature ranging from 19.6 to 31.4°C and an alkaline medium with a pH varies 7.5 to 8.6 (Schaffner *et al.* 2001). The seasonal variations directly affect the growth, development and activities of *Aedes* mosquitoes. The eggs of *Aedes* species are desiccation resistant; this factor is of great entomological consideration because even during the dry season the eggs remain viable.

Physicochemical properties of larval habitats regulate the abundance of mosquito species, for example, *Anopheles* species were found more in natural larval habitats and *Culex* species in artificial larval habitats (Paksa *et al*., 2019; Alahmed *et al.* 2011). In the present study, *Anopheles* species were found in artificial habitats, while *Culex* species were collected from different types of larval habitats, indicating these mosquitoes can live in a wide range of water habitats even in the wastewater. Larval habitats in this study were stagnant, stream and seepage, water container, turbid and clear water, sun exposed or covered from sunlight. Studies showed that some of *Culex* larval species were found a lone or along with other species, such as *Anopheles* and *Aedes* (Alahmed *et al.* 2009) which has been observed in this study.

Conclusion

The large distribution and establishment of potential vectors, such as *Culex, Anopheles* and *Aedes* species in the urban areas, will significantly increase the risk of pathogen transmission. Arbovirus vectors such as *A. aegypti* and *A. albopictus* along with *C. pipiens* and are well adapted to a broad range of habitats and climatic conditions. Determining of distribution and full description of ecology of arboviral vectors habitats conditions in Annaba District have provided important ecological information on establishment of important mosquito borne diseases. This stresses the need for appropriate monitoring and control strategies against this species, and in this way prevent important vectors such as *A. aegypti* and *A. albopictus*, and *C. pipiens* to be increased and established in this area due to changing and developing human activities and weather changes.

References

Adhami J, Reiter P. 1998. Introduction and establishment of *Aedes* (*Stegomyia*) *albopictus* Skuse (Diptera: Culicidae) in Albania *Journal of the American Mosquito Control Association,* 14(3): 340–343.

Aïssaoui L, Boudjelida H. 2017. Diversity and distribution of culicinae fauna in Tebessa district (North-East of Algeria).*International Journal of Mosquito Research,* 4(1): 07–12.

Akiner MM, Demirci B, Babuadze G, Robert V, Schaffner F. 2016. Spread of the Invasive Mosquitoes *Aedes aegypti* and *Aedes albopictus* in the Black Sea Region Increases Risk of Chikungunya, Dengue, and Zika Outbreaks in Europe. *PLOS Neglected Tropical Diseases*, 10(4): 46–64.

Alahmed AM, Al Kuriji MA, Kheir SM, Alahmedi SA, Al Hatabbi MJ, Gashmari MA. 2009. Mosquito fauna (Diptera: Culicidae) and seasonal activity in Makka Al Mukarramah Region, Saudi Arabia. *Journal of the Egyptian Society of Parasitology,* 39(3): 991–1013.

Alahmed AM, Kheir SM, Al Kuriji MA, Sallam MF. 2011. Breeding habitats characterization of *Anopheles* mosquito (Diptera: Culicidae) in NajranProv-ince, Saudi Arabia. *Journal of the Egyptian Society of Parasitology*, 41(2): 275–288.

Aliota MT, Peinado SA, Osorio JE, Bartholomay

LC. 2016. *Culexpipiens* and *Aedestriseriatus* Mosquito susceptibility to Zika virus. *Emerging Infectious Diseases,* 22(10): 1857.

Amara Korba R, Boukraa S, Alayat MD, Bendjeddou ML, Francis F, Boubidi SC, Bouslama Z. 2015. Preliminary report of mosquitoes survey at Tonga Lake (North-East Algeria). *Advances in Environmental Biology,* 9(27): 288–294. DOI: http://hdl.handle.net/2268/196649

Amira K, Chouaib T, Djeghader NEH, Boudjelida H. 2018. Laboratory study of the larvicidal efficacy of a local plant *Hertia cheirifolia* against the most abundant mosquito species, in Algeria. *Journal of Entomology and Zoology Studies,* 6(1): 258–262.

Amraoui F, Ben Ayed W, Madec Y, Faraj C, Himmi O, Btissam A, Sarih M, Failloux AB. 2019. Potential of *Aedes albopictus* to cause the emergence of arboviruses in Morocco. *PLOS Neglected Tropical Diseases,* 13(2): 69–97.

Becker N, Petrić D, Boase C, Lane J, Zgomba M, Dahl C, Boase C, Lane J, Kaiser A. 2010. *Mosquitoes and their control.* Springer, 565 pp.

Benallal KE, Allal-Ikhlef A, Benhamouda K, Schaffner F, Harrat Z. 2016. First report of *Aedes (Stegomyia) albopictus* (Diptera: Culicidae) in Oran, West of Algeria. *Acta Tropica,* 164: 411–413.

Bennett KL, Martínez CG, Almanza A, Rovira JR, McMillan WO, Enriquez V, Barraza E, Diaz M, Sanchez Galan JE, Whiteman A, Gittens RA, Loaiza JR. 2019. High infestation of invasive *Aedes* mosquitoes in used tires along the local transport network of Panama. *Parasites & Vectors,* 12: 264.

Bennouna A, Balenghien T, El Rhaffouli H, Schaffner F, Garros C, Gardès L, Lhor Y, Hammoumi S, Chlyeh G, FassiFihri O. 2017. First record of *Stegomyia albopicta (= Aedes albopictus)* in Morocco: a major threat to public health in North Africa. *Medical and Veterinary Entomology,* 31(1): 102–106.

Blaustein L, Chase JM. 2007. Interactions between mosquito larvae and species that share the same trophic level. *Annual Review of Entomology,* 52: 489–507.

Bouattour A, Khrouf F, Rhim A, M'Ghirbi Y. 2019. First Detection of the Asian Tiger Mosquito, *Aedes (Stegomyia) albopictus* (Diptera: Culicidae), in Tunisia. *Journal of Medical Entomology,* 56(4): 111–115.

Bouaziz A, Amira K, Djeghader NEH, Aïssaoui L, Boudjelida H. 2017. Impact of an insect growth regulator on the development and the reproduction potency of Mosquito. *Journal of Entomology and Zoology Studies,* 5(3): 1662–1667.

Boubidi SC, Gassen I, Khechache Y, Lamali K, Tchicha B, Brengues C, Menegon M, Severini C, Fontenille D, Harrat Z. 2010. *Plasmodium falciparum* Malaria, Southern Algeria, 2007. *Emerging Infectious Diseases,* 16(2): 301–303.

Boudemagh N, Bendali-Saoudi F, Soltani N. 2013. Inventory of Culicidae (Diptera: Nematocera) in the region of Collo (North-East Algeria). *Annals of biological research*, 4(2): 94–99.

Boudjelida H, Bouaziz A, Thomas S, Smagghe G, Soltani N. 2005. Effects of ecdysone agonist halofenozide against *Culex pipiens*. *Pesticide Biochemistry and Physiology,* 83: 115–123.

Boukraa S, De La Grandière MA, Bawin T, Raharimalala FN, Zimmer J-Y, Haubruge E, Thiry E, Francis EF. 2016. Diversity and ecology survey of mosquitoes potential vectors in Belgian equestrian farms: A threat prevention of mosquito-borne equine arboviruses. *Preventive Veterinary Medicine,* 124: 58–68. https://doi.org/10.1016/j.prevetmed.2015.12.013

Brunhes J, Hassaine K, Rhaim A, Hervy JP. 2000. Les Culicidés de l'Afrique méditerranéenne: espèces présentes et répartition (Diptera, Nematocera). *Bulletin de la Société entomologique de France,* 105(2): 195–204.

Brunhes J, Rhaim A, Geoffroy B, Angel G, Hervy JP. 1999. *Les Culicidaes de l'Afrique méditerranéenne, logiciel d'identification et d'enseignement*, IRD France.

Brunhes J, Schaffner F, Angel G, Geoffroy B, Hevry JP, Rhaiem A. 2001. *Moustiques d'Europe. Logiciel d'identification. Institut de recherche pour le développement*, IRD France.

Calistri P, Giovannini A, Hubalek Z, Ionescu A, Monaco F, Savini G, Lell R. 2010. Epidemiology of West Nile in Europe and in the Mediterranean Basin. *The Open Virology Journal,* 4: 29–37.

Campbell GL, Marfin AA, Lanciotti RS, Gubler J. 2002. West Nile virus. *The Lancet Infectious Diseases,* 2: 519–529. https://doi.org/10.1016/S1473-3099(02)00368-7

Chouin-Carneiro T, Vega-Rua A, Vazeille M, Yebakima A, Girod R, Goindin D, Dupont-Rouzeyrol M, Lourenço-de-Oliveira L, Failloux A-B. 2016. Differential susceptibilities of *Aedes aegypti* and *Aedes albopictus* from the Americas to Zika virus. *PLOS Neglected Tropical Diseases,* 10(3): e0004543.

Cornel AJ, Hunt RH. 1991. *Aedes albopictus* in Africa? First records of live specimens in imported tires in Cape Town. *Journal of the American Mosquito Control Association*, 7(1): 107–108.

Daget J. 1976. *Les modèles mathématiques en écologie*. Masson, Paris, 172 pp.

Delatte H, Desvars A, Bouetard A, Bord S, Gimonneau G, Vourc'h G, Fontenille D. 2010. Blood-feeding behavior of *Aedes albopictus,* a vector of Chikungunya on La Reunion. *Vector-Borne and Zoonotic Diseases,* 10(3): 249–258.

Djeghader NEH, Amira K, Boudjelida H. 2019. Preliminary study of the insecticidal activity of the medicinal plant *Anastatica hierochuntica* against *Culex pipiens* mosquito. *International Journal of Advanced Research in Science, Engineering and Technology,* 7(53): 61–64.

Engler O, Savini G, Papa A, Figuerola J, Groschup M.H, Kampen H, Medlock J, Vaux A, Wilson AJ, Werner D, Jöst H, Goffredo M, Capelli G, Federici V, Tonolla M, Patocchi N, Flacio E, Portmann J, Rossi-Pedruzzi A, Mourelatos S, Ruiz S, Vázquez A, Calzolari M, Bonilauri P, Dottori M, Schaffner F, Mathis A, Johnson N. 2013. European surveillance for West Nile virus in mosquito populations. *International Journal of Environmental Research and Public Health*, 10: 4869–4895.

Fontenille D, Traoré-Lamizana M, Zeller H, Mondo M. 1995. Rift Valley fever in western Africa: isolations from *Aedes* mosquitoes during an interepizootic period. *The American Journal of Tropical Medicine and Hygiene,* 52: 403–404. https://doi.org/10.4269/ajtmh.1995.52.403

Gould EA, Higgs S. 2009. Impact of climate change and other factors on emerging arbovirus diseases. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* 103(2): 109–121.

Hammadi D, Boubidi SC, Chaib SE, Saber A, Khechache Y, Gasmi M, Harrat Z. 2009. Le paludisme au Sahara algérien. *Le Bulletin de la Société de Pathologie Exotique,* 102(3): 185–192.

Han LL, Popovici F, Alexander JP, Laurentia V, Tengelsen LA Cernescu Gary CHE Jr., Ion-Nedelcu N, Campbell GL, Tsai TF. 1996. Risk factors for West Nile virus infection and meningoencephalitis, Romania. *The Journal of Infectious Diseases*, 179(1): 230–233.

Hanafi-Bojd AA, Vatandoost H, Oshaghi MA, Charrahy Z, Haghdoost AA, Sed-aghat MM, Abedi F, Soltani M, Raeisi A. 2012. Larval habitats and biodiversity of anopheline mosquitoes (Diptera: Culicidae) in a malarious area of southern Iran. *Journal of Vector Borne Diseases,* 49(2): 91–100.

Hassain K. 2002. Biogéographie et biotypologie des Culicidaes (Diptera : Nematocera), de l'Afrique méditerranéenne. Bioécologie des espèces les plus vulnérantes (*AedesCaspius, Aedes détritus, Aedesmariae et Culex pipiens*) de la région occidentale d'Algérie. Thèse de Doctorat en sciences. Université de Tlemcen, Algérie 186 pp.

Hayes EB, Komar N, Nasci RS, Montgomery SP, O'Leary DN, Campbell GL. 2005.

Epidemiology and Transmission Dynamics of West Nile Virus Disease. *Emerging Infectious Diseases,* 11(8): 1167–1173.

Himmi O, Dakki M, Trari B, Elagbani MA. 1995. Les Culicidaes du Maroc : clés d'identification avec données biologiques et écologiques. Travaux de l'Institut des Sciences, série Zoologie, Rabat. 44: 50–58.

Izri A, Bitam I, Charrel RN. 2011. First entomological documentation of *Aedes (Stegomyia) albopictus* (Skuse, 1894) in Algeria. *Clinical Microbiology and Infection,* 17(7): 1116–1118.

Juliano SA. 2009. Species interactions among larval mosquitoes: context dependence across habitat gradients. *Annual Review of Entomology,* 54: 37–56.

Lafri I, Bitam I, Beneldjouzi A, Benmahdi MH. 2014. An Inventory of mosquitoes (Diptera: Culicidae) in Algeria. *Bulletin de la Société zoologique de France,* 139(1–4): 255–261.

Martens P, Hall L. 2000. Malaria on the Move: Human Population Movement and Malaria Transmission*. Emerging Infectious Diseases,* 6(2): 103–109.

Messai N, Berchi S, Boulknafd F, Louadi K (2011). Inventaire, systématique et diversité biolo-gique de Culicidae (Diptera : Nematocera) dans la région de Mila (Algérie). *Entomologie faunis-tique – Faunistic Entomology,* 63(3): 203–206.

Paksa A, Sedaghat MM, Vatandoost H, Yaghoobi-Ershadi MR, MoosaKazemi SH, Hazratian T, Sanei-Dehkordi A, Oshaghi MA. 2019. Biodiversity of Mosquitoes (Diptera: Culicidae) with Emphasison Potential Arbovirus Vectors in East Azerbaijan Province, *Northwestern Iran. Journal of Arthropod-Borne Diseases,* 13(1): 62–75.

Petrić D, Bellini R, Scholte E-J, Rakotoarivony LM, Schaffner F. 2014. Monitoring population and environmental parameters of invasive mosquito species in Europe. *Parasites & Vectors,* 7:187. http://www.parasitesandvectors.com/content/7/1/187

Pfeffer M, Dobler G. 2010. Emergence of zoonotic arboviruses by animal trade and migration. *Parasites & Vectors,* 3: 35.

Ramade F. 1984. *Eléments d'écologie. Ecologie fondamentale*.Mc Graw-Hill, Paris, 396 pp.

Savage HM, Ezike VI, Nwankwo AC, Spiegel R, Miller BR. 1992. First record of breeding populations of *Aedes albopictus* in continental Africa: implications for arboviral transmission. *The American Mosquito Control Association's,* 8(1): 101–103.

Schaffner F, Angel G, Geoffroy B, Hervy JP, Rhaiem A, Brunhes J. 2001. The mosquitoes of Europe. An identification and training programme. *IRD Ed. & EID Méditerranée*, 2–7099–1485–9.

Scott TW, Weaver SC. 1989. Eastern equine encephalomyelitis virus: epidemiology and evolution of mosquito transmission. *Advances in Virus Research,* 37: 277–328.

Senevet G, Andarelli L. 1960. Contributions à l'étude de la biologie des moustiques en Algérie et dans le Sahara Algérien. *Archives de l'Institut Pasteur, Algérie*, (2): 305–326.

Senevet G, Andarelli L. 1963. Les moustiques de l'Afrique du Nord et du bassin méditerranéen III : Les *Aedes* 2ème partie : Description des espèces du sous genre *Ochlerotatus*, groupe B. *Archives de l'Institut Pasteur, Algérie*, 41: 142–172.

Senevet G, Andarelli L. 1966. Les moustiques de l'Afrique du Nord et du bassin meditérrannéen III : Les *Aedes* 2ème partie : Description des espèces du sous genre *Ochlerotatus*, groupe H. *Archives de l'Institut Pasteur, Algérie*, 44: 51–74.

Spellerberg IF, Fedor PJ. 2003. A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species diversity and the "Shannon-Wiener" Index. *Global Ecology and Biogeography,* 12(3): 177–183.

Turell MJ, Dohm DJ, Sardelis MR, O'guinn ML, Andreadis TG, Blow JA. 2005. Anupdate on the potential of North American mosquitoes (Diptera: Culicidae) to transmit West Nile virus. *Journal Medical of Entomology,* 42(1): 57–62.

Wilkerson RC, Linton YM, Fonseca DM, Schultz TR, Price DC, Strickman DA. 2015. Making mosquito taxonomy useful: A stable classification of Tribe Aedini that balances utility with current knowledge of evolutionary relationships. *PLoS One,* 10(7): e0133602.

Received: 29.09.2020
Accepted: 13.02.2021
Published online: 17.03.2021