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

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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, \textit{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 \textit{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 \textit{et al}. 1992). In North Africa, it was detected for the first time in Algeria in 2014 (Izri \textit{et al}. 2011, Benallal \textit{et al}. 2016), in Morocco in 2015 (Bennouna \textit{et al}. 2017) and in Tunisia in 2018 (Bouattour \textit{et al}. 2019). Despite having a different biogeographical origin, with \textit{A. aegypti} originating from Africa and \textit{A. albopictus} from Asia (Kelly \textit{et al}. 2019), these mosquitoes have converged on a similar ecology, ovipositing in man-made water containers. \textit{A. aegypti} is an urban mosquito feeding exclusively on humans. On the other hand, \textit{A. albopictus} colonizes a larger range of sites and feeds on both animals and humans (Delatte \textit{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 \textit{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 \textit{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 \textit{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 \textit{et al}. 2005, Boudemagh \textit{et al}. 2013, Bouaziz \textit{et al}. 2017, Aïssaoui & Boudjelida 2017, Amira \textit{et al}. 2018, Djeghader \textit{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 \textit{Culex} and \textit{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, \textit{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 recorded 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 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 morphotaxonomy 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: $H' = - \sum P_i \log_2 P_i$ where: $P_i = \frac{n_i}{N}$ (Hence: $H'$: Specific diversity, $n_i$: 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).

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

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

<table>
<thead>
<tr>
<th>Family</th>
<th>Subfamily</th>
<th>Genera</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culicidae</td>
<td>Culex</td>
<td>Culex pipiens Linneaus, 1758</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Culex theileri Theobald, 1903</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Culex modestus Ficalbi, 1890</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culiseta</td>
<td>Culiseta longiareolata Maquart, 1828</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aedes</td>
<td>Aedes albopictus Skuse, 1894</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aedes aegypti Linnaeus, 1762</td>
<td></td>
</tr>
<tr>
<td>Anophelinae</td>
<td>Anopheles</td>
<td>Anopheles labranchiae Falleroni, 1926</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anopheles claviger Meigen, 1804</td>
<td></td>
</tr>
</tbody>
</table>

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 (%).

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

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).

<table>
<thead>
<tr>
<th>Species</th>
<th>Season</th>
<th>Month</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>C. pipiens</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>C. theileri</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>C. modestus</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>C. longiareolata</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>A. labranchiae</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>A. claviger</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A. albopictus</td>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>A. aegypti</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total of species</td>
<td></td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

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

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

that all these species exploit differently the habitats. A total of 5127 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. pipiens 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. aegypti 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 Equitability (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 *Anopheles*. 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. gambiæ* 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. mimicicus, 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.

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