THE FIRST CULICIDAE INVENTORY IN THE REGION OF GUELMA (NORTHEAST ALGERIA)

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ABSTRACT

Multiple studies about mosquitoes were carried out in several regions in northeastern Algeria, but the region of Guelma was not among them; therefore, the current study came to fill this void. Our inventory offered us a close knowledge of the biodiversity of Culicidae taxa in the region of Guelma that helped us define the presence of 12 species belonging to four genera (*Culex, Culiseta, Aedes,* and *Anopheles*). *Culex pipiens* (52.25%) was the most abundant species known in the north-east of Algeria. As well as *Aedes albopictus* being second (22.58%), after its new appearance in the region. Notably, results showed the first record of both *Anopheles multicolour* and *Aedes geniculatus* in the north-east of Algeria.

RÉSUMÉ: Le premier inventaire des Cuculidae dans la region de Guelma nord-est de l'Algerie.

Plusieurs études sur les moustiques ont été réalisées dans les régions du nord-est de l'Algérie, mais la région de Guelma n'en faisait pas partie; par conséquent, la présente étude est donc venue combler ce vide. Notre inventaire nous a offert une connaissance approfondie de la biodiversité des taxons Culucidae dans la région de Guelma, qui nous a permis de définir la présence de 12 espèces appartenant à quatre genres (*Culex, Culiseta, Aedes* et *Anopheles*). *Culex pipiens* (52,25%) était l'espèce la plus abondante connue dans le nord-est de l'Algérie. Ainsi qu' *Aedes albopictus* étant deuxième (22,58%), après sa nouvelle apparition dans la région. Les résultats ont notamment montré le premier enregistrement d'*Anophèles multicolor* et *Aedes geniculatus* dans le nord-est de l'Algérie.

REZUMAT: Primul inventar de Culicidae în regiunea Guelma (nord-estul Algeriei).

Mai multe studii despre țânțari au fost efectuate în mai multe regiuni din nord-estul Algeriei, dar regiunea Guelma nu a fost printre ele; prin urmare, studiul actual a venit să acopere acest gol. Inventarul nostru ne-a oferit o cunoaștere aprofundată a biodiversității taxonilor de Culicidae din regiunea Guelma, care ne-a ajutat să definim prezența a 12 specii cuprinse în patru genuri (*Culex, Culiseta, Aedes* și *Anopheles*). *Culex pipiens* (52,25%) a fost cea mai abundentă specie cunoscută în nord-estul Algeriei. La fel și *Anopheles albopictus* fiind a doua (22,58%), după noua sa apariție în regiune. În special, rezultatele au arătat prima înregistrare atât a *Anopheles multicolor*, cât și a *Aedes geniculatus* în nord-estul Algeriei.

INTRODUCTION

Insects are one of the most important classes of the arthropod phylum and have attracted great interest among ecologists in terms of their large numbers, diversity, economic importance, and health threats (Hubálek and Halouza, 1999). Mosquito-borne diseases are flourishing worldwide and are the most common of all arboviruses: malaria, dengue, West Nile fever, chikungunya, yellow fever, Japanese encephalitis, Western equine encephalitis, La Crosse encephalitis, and Zika fever (Armstrong et al., 2017; Krow-Lucal et al., 2017; Mathew et al., 2017; Aréchiga-Ceballos and Aguilar-Setién, 2015; Harris et al., 2015; Mari and Peydró, 2012; Gubler, 1998). These are a global health threat for both humans and animals. Knowing and understanding these species is necessary to implement a effective control programs. Therefore, these taxa are worth studying.

The surveillance should be designed to detect diseases and provide relevant field-based data for developing and implementing effective control measures to prevent outbreaks before significant public health consequences can occur (Bamou et al., 2021). However, the first and most important step of the control process is to identify the level of numerical density and diagnose the dominant species, because having the proper information about the insects is the key to providing an accurate scientific recommendation. In other words, effective control against mosquitoes depends on the species' life cycle (James et al., 2018).

Mosquitoes are poorly known in Algeria for two reasons: the first is that at every study we discover new distributions of mosquito species, and second, there are regions that have never been the subject of Culicidae inventory, such as the Wilaya of Guelma. Based on that, we don't have a complete picture of the populations that exist in this country.

There were inventoried in all six wilayas in the proximity to Guelma: Annaba (Boulares et al., 2023; Arroussi et al., 2021), El Tarf (Serradj et al., 2018; Houmani et al., 2017; Amara et al., 2016); Souk Ahras (Hamaidia and Soltani, 2021; Hafsi et al., 2021; Hamaidia and Berchi, 2018; Benmalek et al., 2018); Oum El Bouaghi (Messai, 2017); Constantine (Berchi, 1996); and Skikda (Rouari et al., 2022; Chahed et al., 2021; Matoug et al., 2018).

Based on data collected in the region of Guelma, which was treated using different ecological indexes, we came close to understanding the biodiversity and the distribution of Culicidae fauna in that region and its surrounding areas.

MATERIAL AND METHODS

Study area

Guelma is an inland mountain region bordered by the wilayas of Skikda, Annaba, and El Tarf in the north, Constantine in the west, Souk Ahras in the east, and finally, Oum El Bouaghi in the south (Fig. 1). It occupies a major agricultural region at 290 m a.s.l. and has multiple mountains, mainly Mahouna, Dbegh, Houara, Salaoua, and Marmoura. It is very fertile due to large and long rivers, which are oued Seybouse, that extend over 45 km from south to north. Oued Bouhamdane, which has its source in the commune Bouhamdane in the west of the wilaya, Oued Mellah is coming from the south-east. Oued Charef, which takes its source in the south of the wilaya. Guelma also has two dams: Hammam Debagh Dam on Oued Bouhamdane with a capacity of 220 HM^3 and Medjez Beggar Dam (Ain-Makhlouf) with a capacity of 2,8 HM^3.

The climatic conditions characterizing this region were predominantly distinguished by a sub-humid climate (hot summer and warm winter) with an average annual temperature between 7.7°C and 26.4°C and an annual rainfall of 0 to 623 mm according to climate data (*).

Mosquito sampling

Mosquitoes are a group of insects that, in their early stages of development, develop in a high diversity of aquatic ecosystems, including permanent and temporary habitats that can include any receptacle that accumulates water (Rueda, 2008), including the artificial ones. That's why we relied in our inventory on collecting samples of larvae from both natural and artificial aquatic habitats.

This entomological research took place in the breeding season of the year 2022, from April to November, searching for potential breeding habitats for mosquitoes. The inventory has been made by the authors by collecting larvae of mosquitoes at different sites covering the entire wilayas of Guelma (Fig. 1). For that we used the dipping method (Silver, 2008).

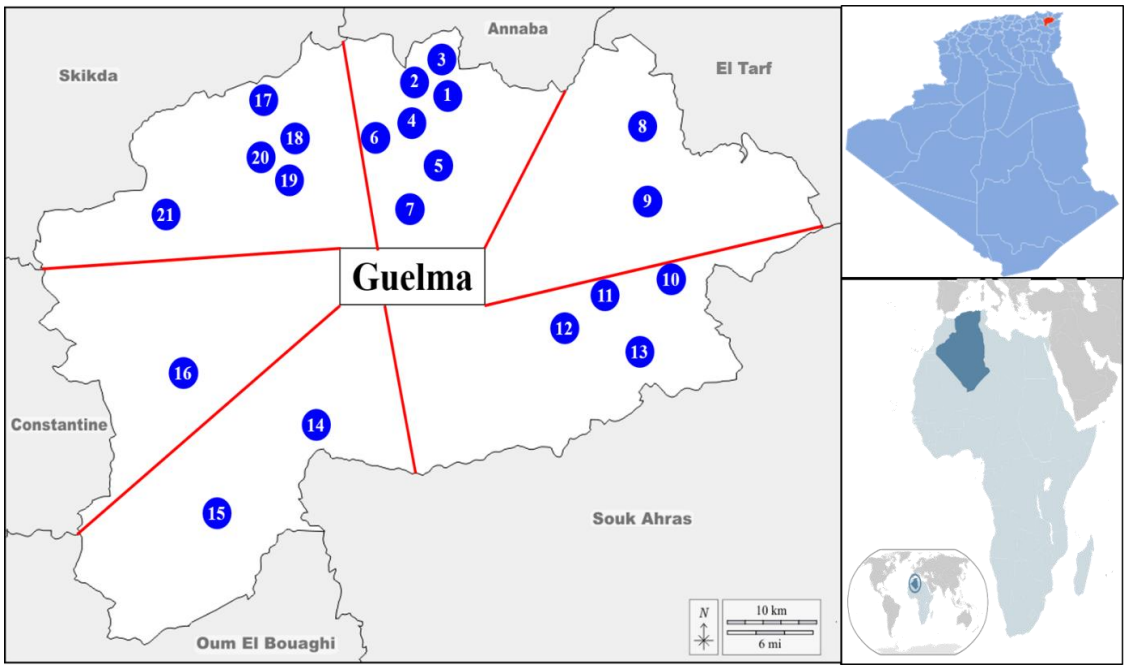

Figure 1: The location of the wilayas of Guelma and the sampling sites.

Overall, 2,435 specimens were collected from 21 stations that were organized into districts according to their closeness to the surrounding regions (Skikda Annaba, El Tarf, Souk Ahras, Oum El Bouaghi, and Constantine).

The purpose was to comparing the collected data with previous studies about the surrounding regions of Guelma.

The details and the geographical characteristics (latitude and longitude) of localities and the type of breeding sites were presented in table 1.

Table 1: Types and characteristics of sampling sites.

Communes	Stations		Type of breeding site	Coordinates	
Nechmaya	Boulekbech	S1	Grass-land pools	36°36.427'N	007°30.090'E
	Merah	S2	Tank	36°36.705'N	007°30.466'E
	Bateh	S3	Bucket	36°36.895'N	007°30.877'E
Heliopolis	Oued chiha	S4	Oued	36°34.998'N	007°25.377'E
	Hammam Bradaa	S5	Swamp	36°32.022'N	007°25.388'E
	Hammam Oulad Ali	S6	Oued	36°33.912'N	007°22.193'E
Guelma	Bourouaih	S7	Ditch	36°28.455'N	007°24.247'E
Oued Fragha	Mogsibaya	S8	Stream	36°33.828'N	007°41.736'E
	Brahmia	S9	Bucket	36° 29.902'N	007° 43.060'E
Bouchegouf	Kraimia	S10	Stream	36°26.252'N	007°41.008'E
Djeballah Khemissi	Layaicha	S11	Swamp	36°27.337'N	007°34.976'E
Boumahra	Douakha	S12	Irrigated pastures	36°26.449'N	007°34.979'E
Hammam N'Bail	Oued Helia	S13	Oued	36°23.739'N	007°36.853'E
Ain Laabi	Hammam bel hachani	S14	Bucket	36°14.196'N	007°20.152'E
Tamlouka	CCLS	S15	Swamp	36°08.987'N	007°08.536'E
Oued Zenati	Saaidia	S16	Bucket	36°19.103'N	007°09.726'E
Roknia	Chtaibi	S17	Oued	36°36.975'N	007°15.546'E
	Roknia I	S18	Well	36°33.281'N	007°14.955'E
	Roknia II	S19	Tank	36°33.412'N	007°15.875'E
	Belmars	S20	Swamp	36°32.466'N	007°14.270'E
Bouhamdane	Bouhamdane	S21	Oued	36°27.971'N	007°06.773'E

Mounting and identification of specimens

The samples collected were taken to the lab and prepared for identification. Larvae were sorted by station and date than stored in labeled tubes containing 70% ethanol. For the identification, we used both the software of the European identification key for mosquitoes (Schaffner et al., 2001), and the African identification key for mosquitoes (Brunhes et al., 2000).

Data analysis

To define the Culicidae fauna diversity in the region of Guelma, we used different statistical tools, graphs, and indices in the present study to assess the diversity between different habitats. The species richness (S) and the number of individuals (Abundance) of each species present were recorded at the study sites. We calculated the relative abundance (RA%). Shannon diversity index (H') to determine the population distribution and each community's diversity value. Also, the equitability (E), which is the relation between the population distribution and the stand structures in the study site, was calculated. In order to get the data set, we used XLStat 2014.

RESULTS

It is worth mentioning that we checked 30 aquatic habitats in the Guelma Region, but we found 21 with for mosquito larvae.

Four genera comprising 12 species, of which over 50% of samples belong to the genus *Culex*. *Aedes* comes secondly with 23.71%, followed by *Culiseta* with 15.82%, and lastly, *Anopheles* with only 3.86% (Fig. 2). As for the species, *Culex pipiens* (52.25%) was the most abundant species. *Aedes albopictus* has 22.58% of the specimens, followed by *Culiseta longiareolata* (15.82%), the only species representative of the *Culiseta* genera. On the other hand, the species accounted for the lowest percentage is *Anopheles multicolor* with only 0.12% (Fig. 3).

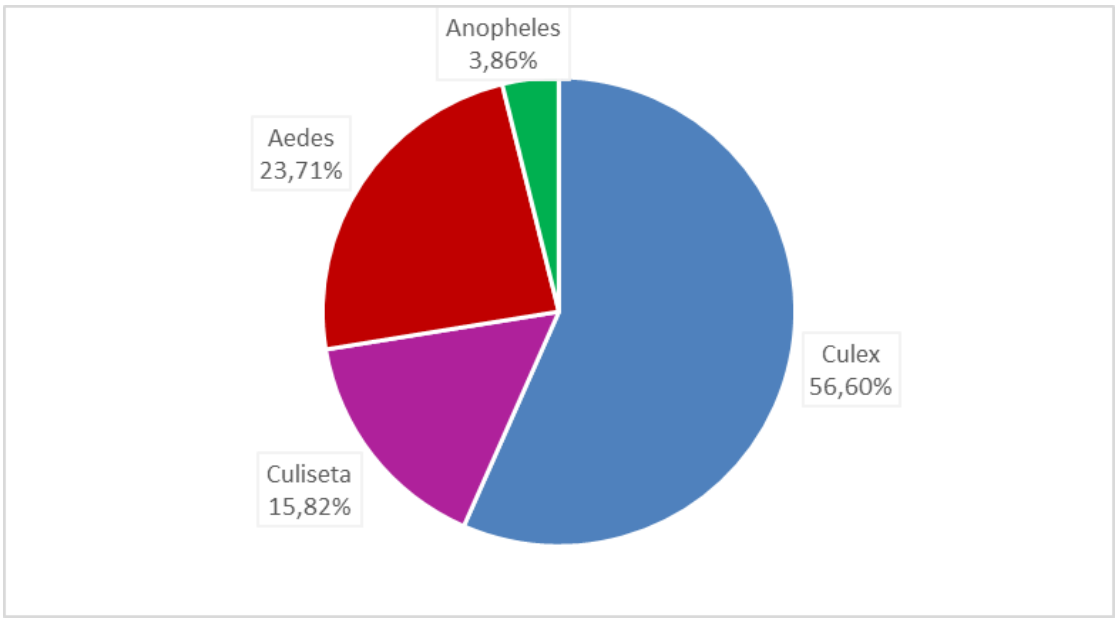

Figure 2: Frequencies of the genera collected in the region of Guelma.

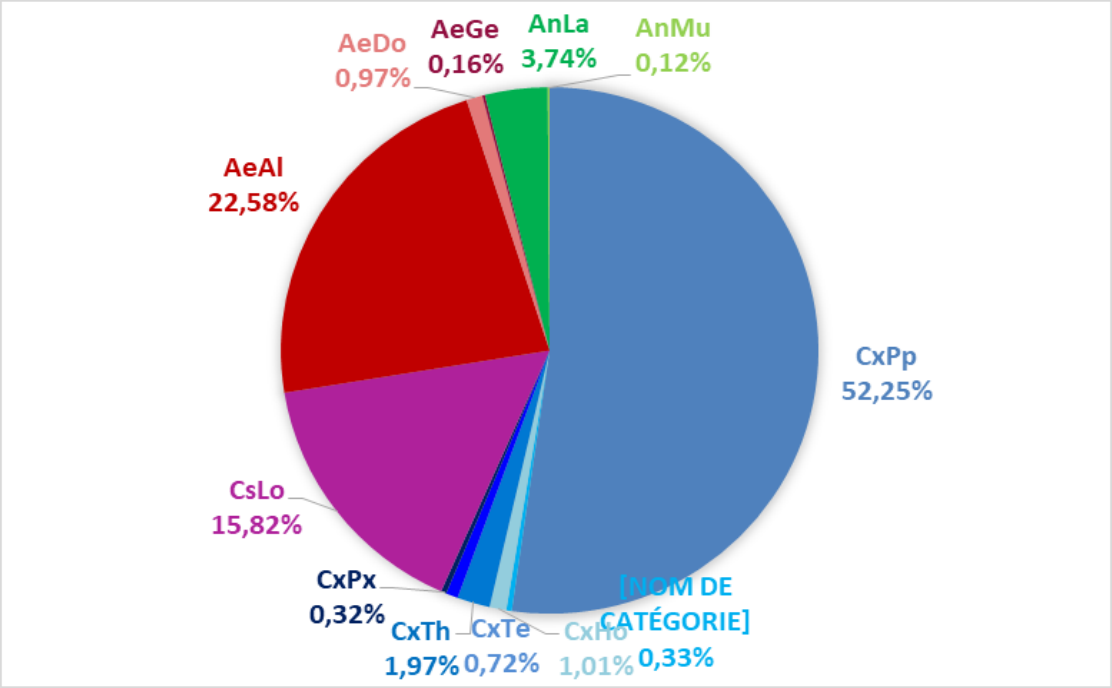

Figure 3: The frequencies of the species collected in the region of Guelma.

Samples collection sites were selected in such a way that they were close to the proximities of the wilayas in order to compare the results with previous studies conducted in those wilayas.

It was found that in the sites near Souk Ahras and Skikda, *Culex pipiens* was the most abundant species (67.59% and 73.02%, respectively), while *Aedes albopictus* species was the most abundant in the sites near Annaba (51.3%) and Tarf (38.49%), and especially Oum El Bouaghi (80.28%) and Constantine (100%). As for the Shannon index, high values were registered in the east of Guelma (Annaba, El Tarf, and Souk Ahras), while in the west (Oum El Bouaghi, Constantine, and Skikda), the lowest values were registered, as shown in table 2. As a remark, in table 2, the area near Constantine is without values for H' and E indexes because we found only one species (*Aedes albopictus*).

Most types of mosquitoes (nine species) were found only in natural breeding sites, and one species (*Aedes albopictus*) was found only in artificial sites, while two species (*Culex pipiens* and *Culiseta longiareolata*) were observed in both habitats.

Figure 4 shows the association between different mosquito species in natural breeding sites where *Culex pipiens* is present with four species: *Culiseta longiareolata*, *Anopheles labranchiae*, *Culex hortinsis* and *Culex martini*. While *Anopheles labranchiae* is frequent with eight species: *Culex pipiens*, *Culiseta longiareolata*, *Culex theileri*, *Anopheles multicolor*, *Culex territans*, *Culex hortinsis*, *Culex perexiguus*, and *Aedes geniculatus*. Besides, *Culex martinii* being found with *Culex pipiens*, it was also found with *Culex territans*. The only species found alone in natural sites is *Aedes dorsalis*.

Table 2: Spatial distribution and diversity indexes and the dominance of mosquito species recorded in the study areas. H': Shannon index, E: Equitability, RA: Relative Abundance (%). (Ae. – Aedes; An. – Anopheles; Cx. – Culex; Cs. – Culiseta).

Sites	H'	E	Species Abundance (RA%)
Near Annaba	1.37	0.66	*Cx. pipiens* (14.94%), *Cx. martinii* (0.65%), *Cx. theileri* (0.65%), *Cx. territans* (2.6%), *Cs. longiareolata* (21.1%), *Ae. albopictus* (51.3%), *Ae. dorsalis* (7.79%), *An. labranchiae* (0.97%).
Near El Tarf	1.33	0.75	*Cx. pipiens* (36.82%), *Cx. perexiguus* (3.35%), *Cs. longiareolata* (17.15%), *Ae. albopictus* (38.49%), *Ae. geniculatus* (1.67%), *An. labranchiae* (2.51%).
Near Souk Ahras	1.02	0.52	*Cx. pipiens* (67.59%), *Cx. hortinsis* (0.64%), *Cx. theileri* (9.38%), *Cx. territans* (2.13%), *Cs. longiareolata* (1.92%), *An. labranchiae* (17.7%), *An. multicolor* (0.64%).
Near Oum El Bouaghi	0.6	0.55	*Cx. pipiens* (15.14%), *Cs. longiareolata* (4.58%), *Ae. albopictus* (80.28%).
Near Constantine	–	–	*Ae. albopictus* 100%.
Near Skikda	0.7	0.39	*Cx. pipiens* (73.02%), *Cx. martinii* (0.54%), *Cx. hortinsis* (2%), *Cx. theileri* (0.27%), *Cs. longiareolata* (24.07%), *An. labranchiae* (0.09%).

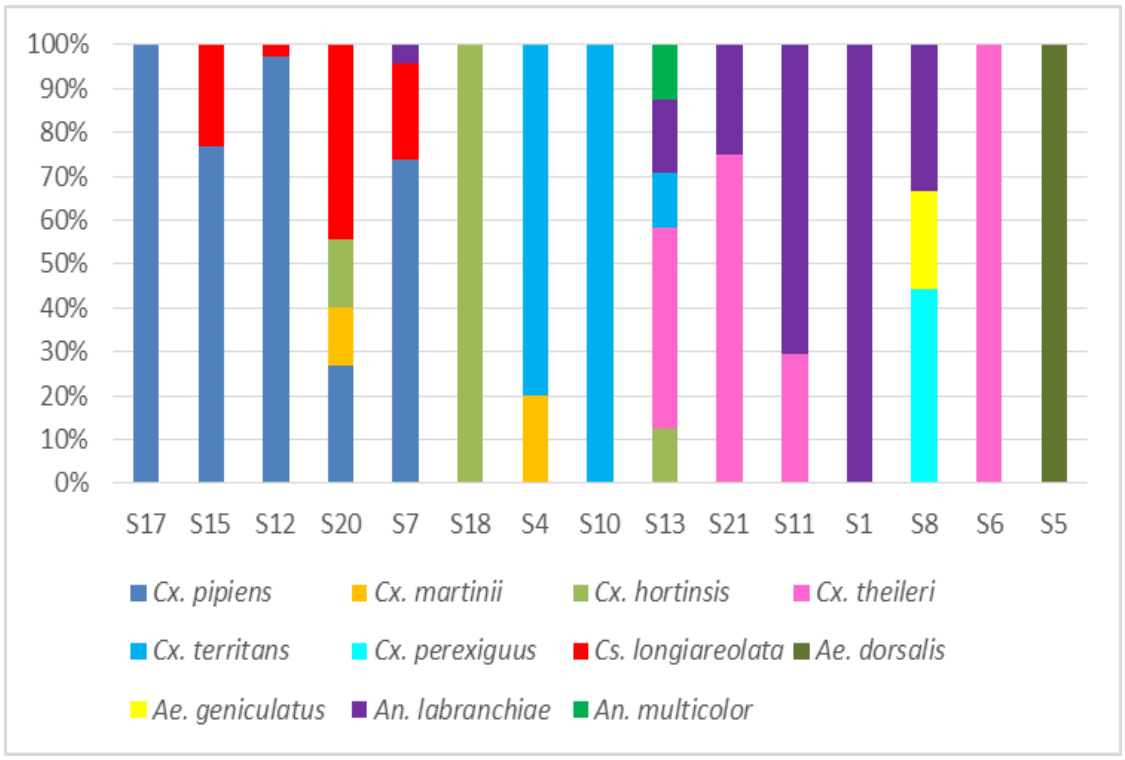

Figure 4: The association of the different species sampled in natural habitats; S-station).

Figure 5 represents the artificial sites species associations, that illustrates the presence of *Aedes albopictus* the species that only resides in artificial habitats in association with both *Culex pipiens* and *Culiseta longiareolata*.

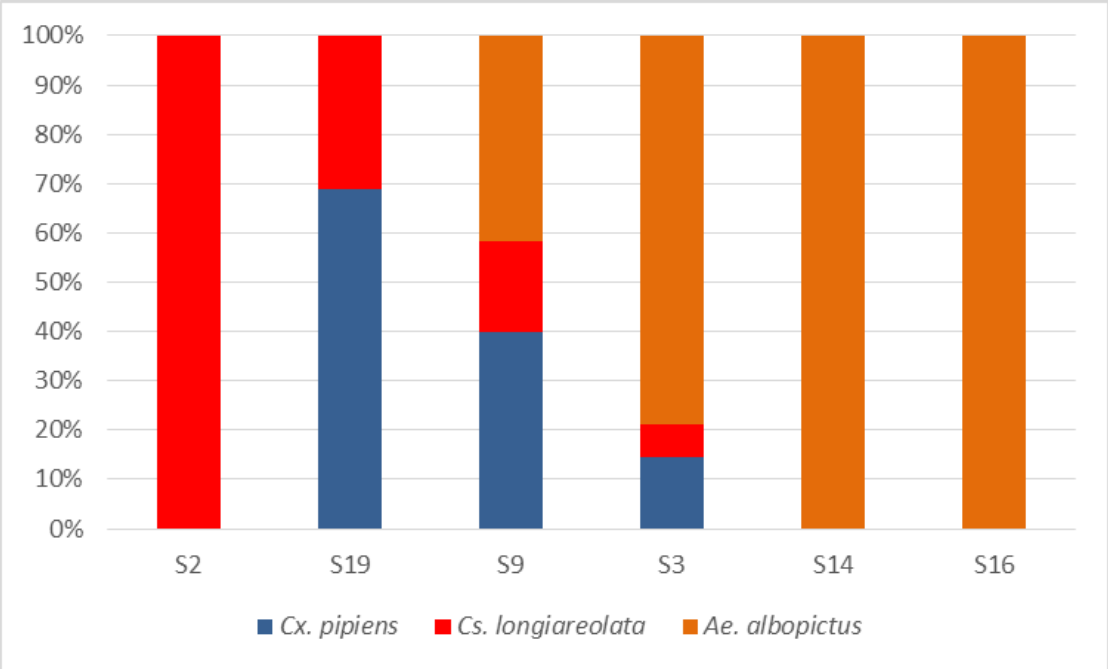

Figure 5: The association of the different species sampled in artificial habitats; S-station.

DISCUSSION

Mosquitoes have been the subject of numerous studies in Algeria, but they have been unorganized, discontinued, and without follow-up. There are areas that have been continuously the subject of Culicidae studies, while there are places that have been discarded and their mosquito populations undiscovered like the region of Guelma till now. This is illustrated by the checklist of mosquitoes by (Merabti et al., 2021).

The Culicidae populations found in the region of Guelma in this study are divided into two subfamilies, Culicinae, which are also composed of the genera *Aedes*, represented by *Aedes albopictus*, *Aedes dorsalis*, and *Aedes geniculatus*. The genus *Culex* is represented by *Culex pipiens* with the highest numbers, *Culex theileri* being the second, followed by *Culex hortinsis* and *Culex territance*, and as accessory species, *Culex martinii* and *Culex perexiguus*. And finally, the genus *Culiseta* is represented only by *Culiseta longiareolata*. For the subfamily Anophelinae with *Anopheles labranchiae* and *Anopheles multicolor*.

According to the studies conducted in the neighboring wilayas of Guelma: Annaba (Boulares et al., 2023; Rouibi et al., 2023; Arroussi et al., 2021); El Tarf (Rouibi et al., 2023; Serragd et al., 2018; Houmani et al., 2017; Amara Korba et al., 2026); Souk Ahras (Hamaidia and Soltani, 2021; Hafsi et al., 2021; Hamaidia and Berchi, 2018; Benmalek et al., 2018); Oum El Bouaghi (Messai, 2017); Constantine (Berchi, 1996); and Skikda (Rouari et al., 2022; Chahed et al., 2021; Matoug et al., 2018), the species that were found are species that are characteristic for the northeastern region of Algeria, except for two species *Aedes geniculatus* and *Anopheles multicolor* that are specific to the state of Guelma.

Natural breeding sites are most diverce habitats for Culicidae larvae in our inventory (11 out of 12 species found) even though artificial habitats have only three species (*Culex pipiens*, *Culiseta longiareolata*, and *Aedes albopictus*) 63% of samples were collected.

Mosquitoes lay their eggs at diverse sites (Machault et al., 2009), and this is related to the quantity and quality of water and the environmental characteristics of the habitat. The data we have is evidence of the difference between species oviposition, where some of them frequent only natural sites and others artificial ones, and some can be found in both.

Culex pipiens is present in most districts, known for its great ecological valence, it is present in about 90% of the prospected lodgings of Guelma which is confirmed by Himmi (2007) in Moroco and Berchi et al. (2012) in Algeria. This was confirmed in the works carried out in the wilayas neighboring Guelma. These results can only confirm this species has great ecological plasticity allowing it to colonize different types of breeding sites (F.A.O., 2009), capable of withstanding the abiotic conditions of different environments (Brunhes et al., 2000).

Anopheles multicolor has been reported from arid areas in Africa north of the Sahara Desert, from Morocco to Egypt, extending further south in the African continent along the Nile River valley and the Red Sea coast (Trari et al., 2017; Hammadi et al., 2009; Ramsdale, 1990; Kenawy et al., 1986). In sub-Saharan Africa, its presence was reported only in Niger, at the extreme northern limit of the country (Coetze, 2020). Therefore, its appearance in our data was expected due its being reported in other regions of Algeria and neighboring countries. The peculiarity of this species in our work is that we found it only in running water.

It is worth nothing that, *Aedes albopictus*, as known as the Asian tiger mosquito, was found in stations close to Annaba, where its presence had already been confirmed (Rouibi et al., 2023; Arroussi et al., 2021), as well as at El Tarf (Rouibi et al., 2023), Souk Ahras (Hafsi et al., 2021; Hamaidia and Berchi, 2018) but this species hasn't been found in both Oum El Bouaghi and Constantine yet, but our data of Guelma makes finding it there possible.

Meanwhile *Aedes geniculatus* was only found in one studied site in the wilaya of Guelma, and the studies carried out in all neighboring wilayas did not record it. Knowing that this species can be found in forest areas and moves a little (Wagner and Mathis, 2016).

The results showed a difference between the eastern and the western regions of Guelma, this is dependent on their biogeographical characteristics. When comparing the results with near wilayas, we concluded: 1. The biodiversity in the east of Guelma is richer in species than the west; east has 12 species and west seven). 2. Prior studies in the near wilayas on the west of Guelma have not found *Culex martinii*. As for *Aedes albopictus* that we found with large abundance is only declared in the wilaya of Skikda (Chahed et al., 2021). 3. The prior studies in the neighboring wilaya on the east of Guelma have not found *Aedes dorsalis. Culiseta longiareolata* was not noted in references in the Wilaya of El Tarf and *Culex martini* was not declared in El Tarf and Annaba. 4. *Anopheles multicolor* and *Aedes geniculatus* are among the species that lives in Algeria (Robert et al., 2019; Benhissen et al., 2018, 2017; Merabti et al., 2017; Merabti, 2016; Lafri et al., 2014; Hammadi et al., 2009; Brunhes et al., 2000), but they have never been found in the north east of the country. So, this is the first detection of both of them in the wilayas of Guelma and therefore in northeastern Algeria which make their appearance in neighboring wilayas possible.

The species present with low proportions are: *Culex theileri* (1.97%), *Culex martinii* (0.32%), *Culex hortinsis* (1.01%), *Culex territans* (0.72%), *Culex perexiguus* (0.32%), *Aedes dorsalis* (0.97%), *Aedes geniculatus* (0.16%), *Anopheles multicolor* (0.12%). These

percentages may reflect the beginning of the presence of these species in the region or their decline from previous high percentages, which will be confirmed in later works.

In natural sites *Culex pipiens* and *Anopheles labranchiae* are mostly present, so they are more tolerant. While we came across *Culex pipiens* with *Culiseta longieriolata* in the natural sites as proved by Moslov (1989), and these two species are also found in artificial sites with *Aedes albopictus* where the later exists only in artificial sites.

The importance of this study lies in identifying the distribution of mosquitoes in Guelma and its environs and thus identifying the extent of the spread of disease vectors, as some of the species that we found, according to Moslov (1989) and Zeller and Schuffenecker (2004), are carriers of mosquito-borne pathogens such as the West Nile.

CONCLUSIONS

In this first study of Culicidae species inventory in the wilayas of Guelma, and after selecting collection points in diverse areas of the wilaya, we conclude that: the Culicidae populations in our study area is divided into Culicinae and Anophelinae. These species have preferences when it comes to their breeding habitats some prefer natural sites and others artificial sites depending on quantity and quality of water and the environmental characteristics of the habitat. Both *Culex pipiens* and *Culiseta longiareolata* can live in natural and artificial habitats due to their great ecological valences. *Anopheles multicolor* might need more study to realize if its presence in here was due to climate change or due to the need of a new habitat. We have to highlight the possibility of finding *Aedes albopictus* in other areas close to Guelma. Meanwhile *Aedes geniculatus* could be picky about its breeding habitat therefore it wasn't found in many sites. The diversity in the east of Guelma is richer in species than in west, due to climatic factors and geographic characteristics. *Anopheles multicolor* and *Aedes geniculatus* presence in the north east of Algeria needs to be explained in deeper studies.

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