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Analysis of the Culicid Fauna (Diptera: Culicidae) in the Swamps of the Town of Souk el Arbaa, Morocco

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Abstract

The order Diptera and the suborder Nematocera include blood-sucking insects known as Culicidae. They are prominent either because they act as vectors for pathogenic organisms of certain species or due to the nuisance they cause. To better understand the habitat of these mosquitoes in the Souk El Arbaa region (north of Rabat), monitoring of certain physico-chemical parameters was conducted from February 2012 to September 2013. This was aimed at providing information on the optimal conditions for larval development and the factors that restrict them. The waters in the two city swamps show very similar results from the physicochemical analysis, but the Mda River waters seem to be much more contaminated. Mosquitoes appear to be drawn to waters high in organic matter and ammoniacal nitrogen, which causes them to proliferate and grow quickly in the area. In a similar vein, temperature is a major factor in mosquito growth acceleration. The systematic study of Culicidae collected from the various sites surveyed in Souk-El Arbaa revealed the presence of 5 species belonging to the genus: Culex (Culex pipiens, Culex theileri, Culex prexiguus, Culex impudicus and culex quinquefasciatus). The bioecological study indicates that the inventoried population is diverse. The most abundant species are respectively Culex pipiens, Culex theileri, Culex quinquefasciatus and Culex prexiguus. It is essential to note that certain physico-chemical parameters favor the development of larvae and the proliferation of mosquitoes, while others limit it.

Subject Areas

Public Health, Environmental Sciences

Keywords

Physicochemical, Culicidae, Biotope, Larvae, Mosquito, Morocco

1. Introduction

The morphology of the Mosquito is directly linked to its way of living. This insect has an aquatic phase for the preimaginal stages (eggs, larva and nymph) and an aerial phase during which the adults generally have a great dispersal capacity.

The peri-urban epigeum deposits of Souk el Arbaa du Gharb are the storage place for nitrogen and phosphate products coming from wastewater from surrounding towns and agricultural land. Disturbance of the natural environment encourages the emergence of species harmful to humans, notably mosquitoes.

The different study stations are distinguished mainly by their dimensions, their depths, their water periods and their aquatic vegetation. These various deposits present different conditions (topography, hydrogeological, floristic and physicochemical) favoring the development of Culicidian fauna, which leads to disturbances in the surrounding towns.

By station, we mean the area of the surveyed environment where the culicidae capture sites are located. In order to carry out this task, we selected three places of residence. These biotopes favorable to the development of culicidae (resting and egg-laying environments) were selected based on their environmental interest and their proximity to populations.

In the first part of our study, we carried out a systematic inventory of mosquito species in the Souk el Arbaa region. In the city, inventories were carried out, with the different cities which are our study stations (Dâadaâ and Hay Salam). In the peripheral region, another station was selected to represent rural areas (Mda River).

In the second part of our work, we will examine the elements that influence the density and proliferation of mosquitoes.

2. Study Materials and Methods

2.1. Study Zone

On the national road RN No. 1 between Kenitra and Larache, the town of Souk el Arbaa is located on the northern border of the Gharb plain, 120 km from Rabat. In December, The average temperature fluctuates between 13˚C and 26˚C in August; the annual average precipitation is 700 mm. The dry season lasts quite long and extends from June to September. The stations (larval breeding sites) were selected based on their accessibility, and their abundance of stagnant water where the culicids develop, as well as their proximity to urban areas.

2.2. Water Analysis Technique

Sampling of the waters of the Mda River and the two swamps (Hay Salam and Dâadaâ) was carried out monthly. And the samples, intended for physicochemical analysis, were carried out and preserved according to the general guide for the conservation and handling of samples according to ISO 5667/3 (1994) [1]: namely: The PH, Temperature, electrical conductivity and dissolved oxygen are measured in situ using a multi-parameter analyzer model CONSORT 535, on the other hand all other parameters are determined in the laboratory of the Faculty of Sciences Ibn Tofail University Kenitra and at the environmental laboratory in Rabat (BOD5, COD, chlorides, nitrates, nitrites and ammonium) [2]-[5].

2.3. Larval Sampling Technique

Sampling is done using the ladle method with a capacity of 500 milliliters. This technique consists of immersing the ladle in water then moving it with a uniform movement avoiding swirls.

2.4. Culicidae Identification Techniques

To avoid any confusion, the larvae and nymphs collected were reared until adult mosquitoes were obtained (Koné *et al.*, 2013) [6]. Identification was carried out using the identification keys from the Mediterranean basin mosquito identification software (Brunhes *et al.*, 1999) [7].

3. Results & Discussion

3.1. Specific Richness

The count of the fauna associated with Culex pipiens suggests in principle a low specific richness. This parameter corresponds to the total number of species recorded in the different stations surveyed during the study period (Ramade, 1982) [8].

The values of species richness in the three study stations show that the Hay Salam station is represented by three species, while at Mda River we note the presence of two species, and the Dâadaâ station is represented by a single species (**Table 1**).

Figure 1, represents the illustration of the distribution of specific richness in the surveyed stations.

Table 1. Distribution of species richness in the study stations.

Study Stations	Mda River	Dâadaâ	Hay Salam
specific richness (S)	2	1	3
global specific richness		5	

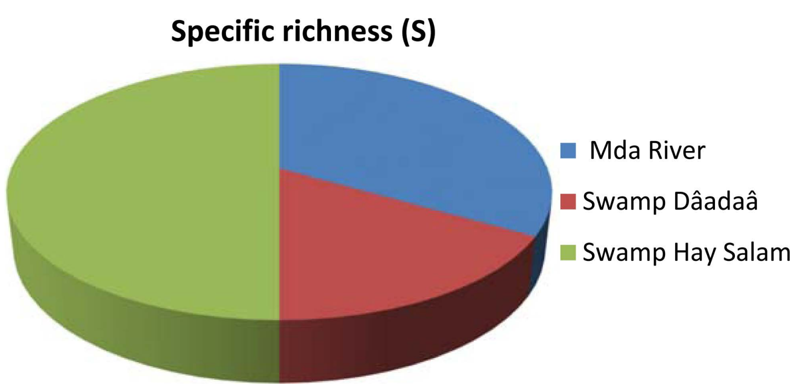

Figure 1. Distribution of species richness in the stations.

3.2. Physicochemical Characteristics of Swamps

In the figures below we have plotted the averages of the physicochemical results of the waters of the three deposits according to the seasons. Thus, the average BOD5 values are of the order of 143.75 mg/l for Mda River, 32 mg/l for Hay Salam and 16 mg/l for Dâadaâ.

According to Martin (1979) [9], BOD5 levels exceeding the value 10 mg/l represent an abnormal situation where the nuisance caused by organic matter is very significant.

Organic pollution is remarkable between May and October, and the Hay Salam station has a peak in August, this is explained by the effect of water evaporation during the summer and discharge of wastewater into the swamp (see **Figure 2**). The results obtained during the summer and autumn seasons are lower than those found in Fez (El Ouali *et al.*, 2011) [10] and those found in Algeria: 122 mg/l in Ain El Arbaa; (Boualla Nabila *et al.*, 2011) [11].

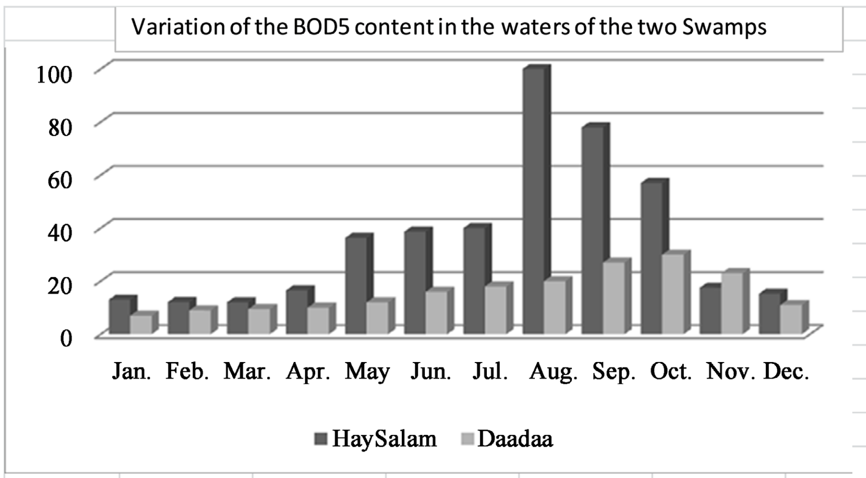

Figure 2. Monthly variation of the BOD5 content in the waters of the two Swamps.

The deposits are characterized by low oxygen contents which vary from 0.66 mg/l to 1.64 mg/l in the two Hay Salam and Mda River stations, during the summer and autumn seasons. This is probably due to the contributions of organic waste, the results obtained are lower than those found at Oued Boufekrane (Houda Lamrani *et al.*, 2011) [12].

The significant fluctuations obtained for ammonium at the three deposits present a slight difference, the latter mainly comes from the decomposition of natural proteins contained in phytoplankton and microorganisms.

According to Martin (1979) [9], ammonium is a pollution factor responsible for water quality. From the point of view of contents, it is reported that the average concentration of ammonium ion present in Mda River is of the order of 11.53 mg/l It is of the order of 12.41 mg/l for swamp Dâadaâ and (10.43 mg/l) for swamp Hay Salam (see **Figure 3**).

The seasonal evolution of water temperature at the swamps is characterized by lower values during the cold season and higher values in summer.

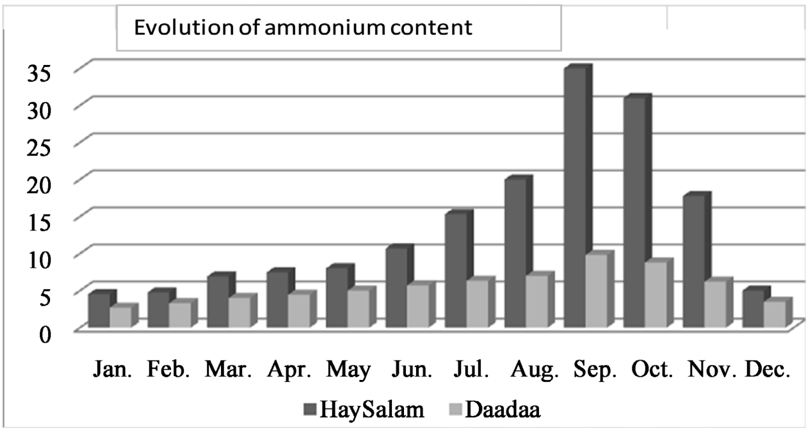

Figure 3. Evolution of the ammonium ion content in the waters of the Hay Salam and Dâadaâ stations.

The average temperature values recorded are around 20.45˚C for Hay Salam and around 18.54˚C for Dâadaâ. The temperature recorded at the level of the Swamps "Dâadaâ and Hay Salam" is higher than that found at the level of Mda River. This is due to the warming of the swamps by the air temperature during the summer period (see **Figure 4**). The differences between the minimum and the maximum are variable; we note a difference of 4.5˚C to 10˚C in the swamp.

These thermal differences can be explained by the duration of water stagnation and plant cover. The thermal differences recorded at the swamps are due to the plant cover and the duration of water stagnation and atmospheric warming. The results obtained at the swamps level are higher than those found in Fez (El Ouali lalami *et al*., 2011) [10].

According to the Moroccan standard for classification of surface waters described in Ministerial Decree No. 1275-01 2002 (Official Bulletin No. 5062, 2002) [13], the waters of the Swamps studied belong to a poor quality class.

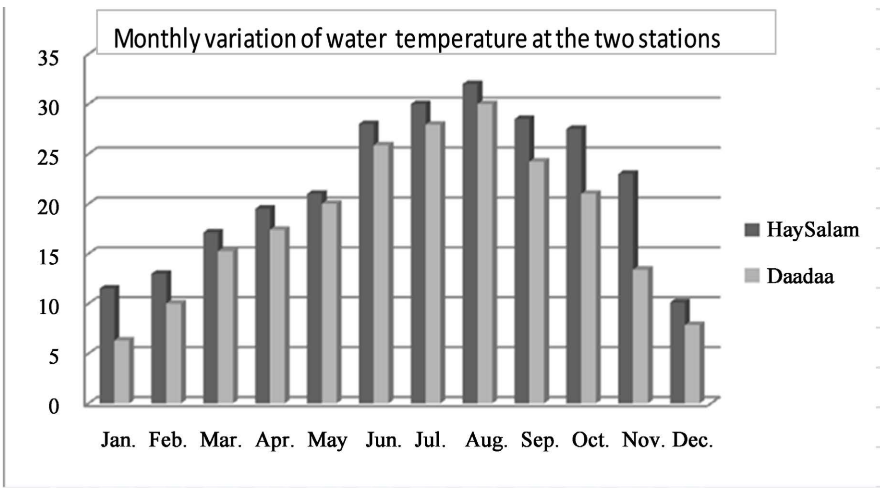

Figure 4. Monthly variation of water temperature at the two Swamps.

The Suspended Solids rate recorded in the Hay Salam and Dâadaâ stations during the summer and autumn is less significant (see Figure 5). These materials are therefore considered vectors of pollution, because many pollutants, particularly heavy metals, are absorbed by these particles. The high level of suspended solids will produce large quantities of sludge in the receiving environment.

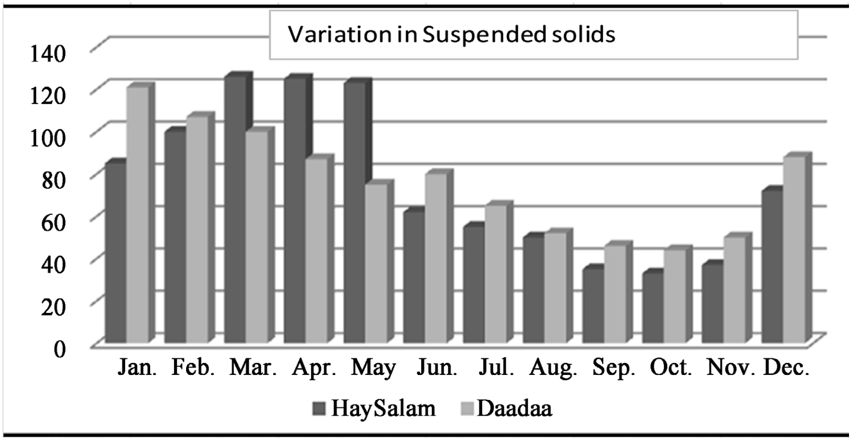

Figure 5. Monthly variation of Suspended Solids concentrations in swamps waters.

The pH of the water in the lodges is alkaline due to the limestone nature of the land. Thus the values vary between 7.39 and 8.45 in the three stations. The maximum pH was recorded in the Hay Salam station, while the Dâadaâ station is less alkaline.

Nitrates (NO_3^-) vary little from one deposit to another. The latter have average values that vary from one station to another, due to the mechanisms of nitrogen elimination, thus making it possible to characterize each station.

The remarkable nitrate content recorded at the Dâadaâ station results from the surrounding agricultural land.

The average concentrations of chlorides in the waters of the swamps range between 87 and 340 mg/l; the high concentration recorded at the Dâadaâ station is attributed to the discharge of wastewater rich in mineral elements and drinking water rich in chlorides. And that the chloride contents recorded at the level of the River are much higher than those of the swamps.

The average electrical conductivity concentration values recorded at swamp Hay Salam vary between 1743 µs/cm in winter and 2800 µs/cm in summer, those recorded at swamp Dâadaâ vary between 1149.77 µs/cm in winter and 2320 µs/cm in summer, on the other hand at the level of Mda River they vary between 1113.3 µs/cm in winter and 2350 µs/cm in summer.

3.3. Fluctuations in Preimaginal Mosquito Populations

The structure of the larval breeding sites is essentially influenced by the plant cover: the screen it forms reduces evaporation, which favors the slope and the conservation of the eggs of certain species (Louah, 1995) [14].

In Souk el Arbaa, generally speaking, culicidienne production at the larval breeding sites is much greater in the rainy season than in the dry season (see Figure 6).

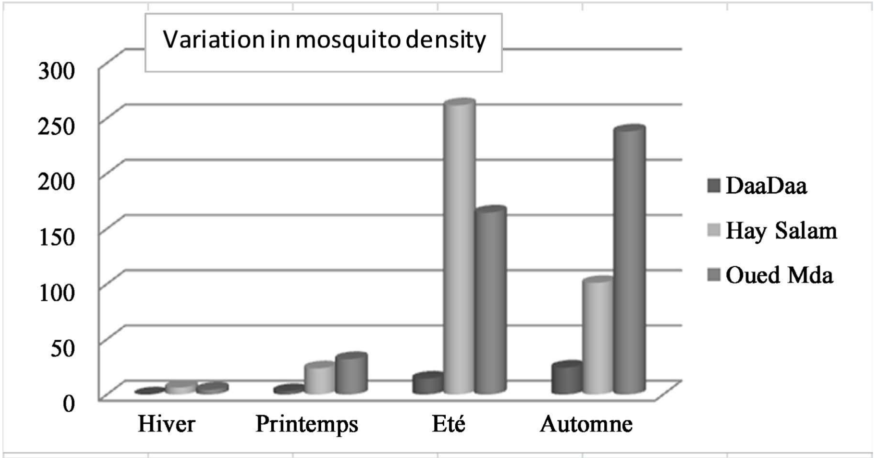

Figure 6. Variation in mosquito density depending on the seasons.

This difference is to a large extent linked to precipitation which, due to rain, creates and replenishes water in numerous open-air deposits.

The various prospected deposits are largely dominated by Culex pipiens both spatially and temporally, at the station level, it is present all year round in the Hay Salam and Mda River stations.

At the Mda River and Dâadaâ stations, maximum development is reached in autumn; while at Hay Salam station, it is reached in summer.

We could detect the decrease in the water level in the two swamps surveyed during our study period.

According to Dajos (1985) [15], the presence of dissolved oxygen constitutes an obstacle to the development of higher aquatic forms. However, it seems that the species discovered are not affected by this parameter, which reflects the high densities observed during summer and autumn in the Hay Salam and Mda River stations.

Nitrite and nitrate levels are reported to have detrimental effects on larval density. This can be explained by, The conversion of ammonia to nitrite then to nitrate, which results in a decrease in the ammonia concentration. And by the excessive multiplication of plants (Eutrophication phenomenon).

The results obtained indicate an increase in temperature, during summer and autumn, in the two swamps (Dâadaâ and Hay Salam). This is explained by the high evaporation during the summer season, which leads to an increase in the content of dissolved salts in the water. According to Trari (1991) [16], Culex pipiens is adapted to high salinity levels. Temperature is positively related to larval density, which confirms the results previously obtained by Ghazi (1995) [17].

During the summer and fall, there was a low concentration of oxygen and a high concentration of organic matter (BOD5). The fact that the roosts have high larval densities depending on the low oxygen levels suggests that the species Culex pipiens does not seem to be affected by this parameter. Pregnant females are more attracted to polluted water than to less polluted water (Subra, 1973) [18].

3.4. Faunistic Characteristics of Breeding Sites

The degree of organization is a fundamental characteristic of any population (Daget, 1976) [19]; typically, in a given environment, a high diversity index is observed when living conditions are favorable. If not, recorded data are low. According to Bigot and Bodot (1973) [20], when living conditions are favorable in an ecosystem, a large number of species can be observed, each represented by a number of individuals, resulting in a high diversity index.

Conversely, when conditions are unfavorable, only a limited number of species are found. In the surveyed breeding sites, the appearance of collected species differs depending on the collection period. Thus, the most abundant species is Culex pipiens, which is considered a constant species. The three species, Culex theileri, Culex prexiguus, and Culex quinquefasciatus, can be considered regular species in our study region.

Indeed, the presence of Culex pipiens was observed throughout the year at the stations, except at the Dâadaâ station during winter, which may be due to the observed temperature drop in the region during winter. Conversely, increased temperature has a beneficial effect on the density of a pre-imaginal population by accelerating the growth rate of larvae and nymphs (Subra, 1973) [18]. This explains the disparity in density observed between February and August in the three studied sites.

In the region, Culex pipiens has a distribution area extending from Skhirate to Kenitra (Himmi *et al.*, 1998) [21]. Berchi (2000) [22] reported its presence in urban and suburban areas of Constantine, especially in breeding sites rich in organic matter.

The second species, Culex theileri, is present with low frequency at the Hay Salam station. According to Brunhes *et al.* (1999) [23], this species is found in various types of habitats and leaves its habitat during winter and summer. Several authors mention that this species cannot tolerate extreme temperatures (winter and summer).

According to Himmi *et al.* (1998), Culex theileri has been discovered in various regions of Morocco, such as Chiahna (Skhirate), the well of Sidi Amira (North of Rabat), and the Daya of Sidi Boughaba (Kenitra). This species is also reported in Algiers, Oran, and Constantine by Senevet and Andareli (1960) [24].

Culex prexiguus, a rare species associated with Culex theileri at the Hay Salam station is reported as a vector of West Nile virus, Sindbis virus, and Rift Valley Fever (Brunthes *et al.*, 1999) [23]. It has various preferred habitats, some of which are very rich in organic matter. According to Himmi *et al.* (1998) [21], this species has been reported in the region from Salé to Temmara. Meanwhile, Lounaci (2003) [25] discovered this species in the marsh of Reghaia.

Culex quinquefasciatus is the fourth frequently observed species at the Mda

River station, associated with Culex pipiens. It is a highly anthropophilic mosquito whose females primarily bite indoors at night. With urbanization and human activity, its distribution range continues to expand, and it is beginning to establish in many rural areas (WHO, 1992) [26].

Culex impudicus Ficalbi, which emerged in 1890, emerged in the two roosts (Dâadaâ and Hay Salam). The species only had two generations between October and June. The larvae hatch from 2 to 3 weeks (spring) to almost two months (winter). According to Himmi *et al.* (1998) [21], this species is present in the region of Rabat and Kenitra. This species shows a preference for fresh or slightly brackish water, it can withstand very high concentrations of dissolved salts) (Louah and al.,1995) [27].

The increased use of laundry detergents and industrial soaps in recent years, due to improved living standards, has also had a significant impact by altering the nature of wastewater, thereby favoring the development of this species at the expense of others.

Inventory of species captured in the region.
Family: Culicidae
Subfamily: Culicinae
Tribe: Culicini
Gender: Culex
Species:
Culex (Culex) pipiens Linné 1758
Culex (Culex) theileri Theobald 1903
Culex (Culex) perexiguus Theobald 1901
Culex (Culex) quinquefasciatus 1823
Culex (Culex) impudicus Ficalbi, 1890

3.5. Quantitative Evolution of Larval Population

According to seasonal larval density values (see **Figure 5**), it appears that winter and spring are characterized by low individual densities, while summer and autumn show high larval densities. It is also noted that there is a slight disparity between the two stations of Hay Salam and Mda River. Meanwhile, the density at the Dâadaâ station is low because the water there is less polluted, with ammonium levels around 8.24 mg/l in autumn and relatively high levels of dissolved oxygen. These results can be attributed to the presence of vegetation in place, which provides additional oxygen through photosynthesis.

A significant population surge is observed at the Hay Salam station during summer and autumn, coinciding with high temperatures and high concentrations of ammonium and organic matter (BOD5) (see **Figure 7**).

Therefore, the mosquito exhibits an autumn-summer cycle, with low development rates linked to decreasing temperatures and water dilution during winter. According to **Figure 8** and **Figure 9**, the Mda River and Dâadaâ stations experience high development rates during autumn, suggesting that the Culex pipiens mosquito undergoes an autumnal cycle.

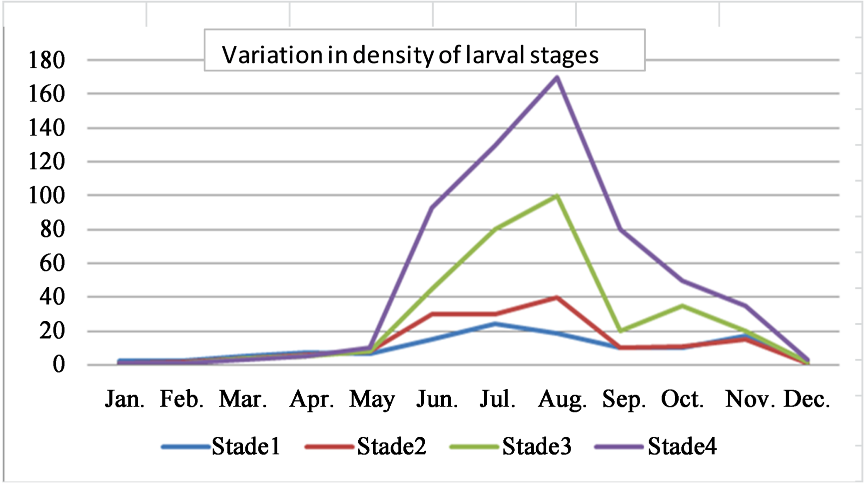

Figure 7. Evolution of the variation of larval stages during the present study (**Hay Salam Station**).

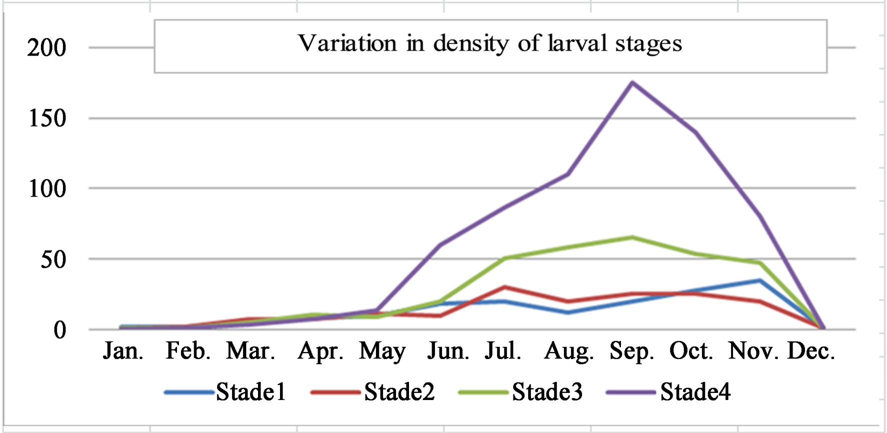

Figure 8. Evolution of the variation of larval stages during the present study (**Station Dâadaâ**).

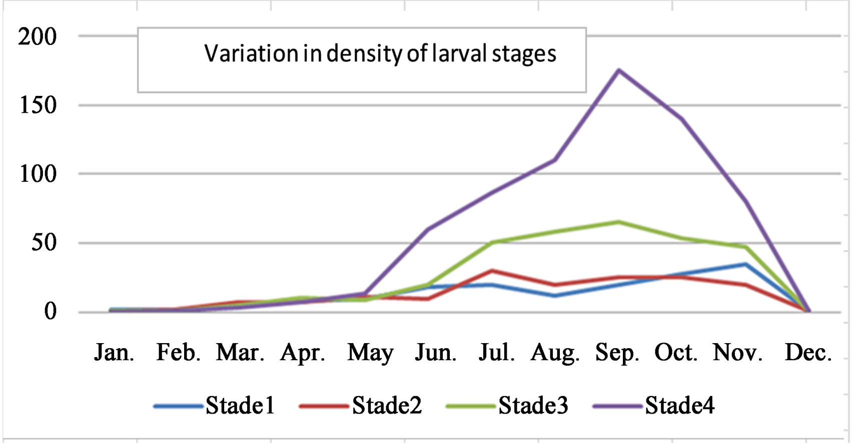

Figure 9. Evolution of the variation of larval stages during the present study Station (**Mda River**).

3.6. Intraspecific Competition

According to some researchers, the accumulation of toxic waste discharged by Culex pipiens larvae during their development can slow their growth or even lead to significant mortality among older larvae. ROUBAUD and GASCHEN (1932) [27] emphasize that this toxicity of waste is particularly significant when larvae are introduced into waters previously used for other breeding purposes. An abundance of food does not necessarily mean an increase in the number of predators. The latter colonize breeding sites due to the disappearance of certain natural predators or competitors (such as Culex cinereus Theobald, 1901, and Culex nebulosus) of the Culex species.

4. Conclusions

Alongside the physicochemical study, a contribution was made to the inventory of Culicidae fauna during the study period. Three breeding sites were surveyed, allowing us to conclude that most Culicidae species and associated fauna appear when climatic conditions are favorable.

Regarding the seasonal frequency of species captured in the breeding sites, it is noted that they exhibit two peaks, in summer and autumn.

The diversity of Culicidae is limited and varies from one station to another, closely related to the physicochemical and abiotic characteristics of the larval habitats. It is observed that larval density varies significantly by season, leading to species zonation.

The studied parameters indicate that the breeding site must be rich in chloride and organic matter, as well as ammoniacal nitrogen, to allow mosquitoes to develop rapidly and reach high densities. Thus, the interaction between abiotic parameters and mosquito larval populations leads to an increase in development rate, resulting in a significant expansion of this mosquito species.

We can identify two essential factors in this study: the physicochemical factor characterized by organic matter, electrical conductivity, and ammonium ions; and the seasonal factor. As the rainy season progresses, open breeding sites will retain water longer and their positivity will increase.

Furthermore, this study, which represents a first step towards developing a database for the city, deserves to be revisited and expanded to establish a definitive list of Culicidae in the Souk el Arbaa region, aiming to complete the distribution map on a national scale.

This work would also deserve to be deepened using new approaches (epidemiological behavior, molecular biology) which could perhaps elucidate certain problems.

Conflicts of Interest

The authors declare no conflicts of interest.

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