Bulletin of Pure and Applied Sciences
Zoology (Animal Science), Vol.41A, No.1,
January-June 2022: P.86-100

Print version ISSN 0970 0765
Online version ISSN 2320 3188
DOI: 10.5958/2320-3188.2022.00012.2

Content Available online at: https://www.bpasjournals.com/zoology

Original Research Article

Bioecology of Culicidae (Diptera: Nematocera) in North Central Algeria

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Article Info:
Received on 10.11.2021
Revised on 29.04.2022
Accepted on 15.05.2022
Published on 15.06.2022

ABSTRACT:
The preimaginal bioecology of Culicidae was studied in north central Algeria for a year in 7 breeding sites, including 3 in Algiers, 3 in the Marais de Réghaia and 1 near the Sébaou river in Tizi-Ouzou. 13 Culicide species have been identified, including one belonging to Anophelinae and 12 to Culicinae. In the suburban Algiers region, the most abundant of which are *Culiseta longiareolata*, an ornithophile species with 57% of collections and *Culex pipiens*, antropophilic species with 39%. In the Sébaou river *Culex pipiens* largely dominates with 86%. The Réghaia marsh has the highest specific richness; the most abundant species are *Culex impudicus* with 44%, batracophile species and *Culex pipiens* with 28%. The spatiotemporal dynamics of *Culex pipiens* deposits, *Culex. impudicus* and *Culiseta longiareolata*, shows that the methods of impoundment of the sites and the variations of the physico-chemical factors of the water cause the eggs to hatch, give rhythm to the functioning of the sites and their productivity. The intensity of emergence is highest during the spring and fall season. In addition, the amplitude of the hibernation period and the speed of development of the generations are influenced by the vagaries of the sub-humid climate. This study contributes to the understanding of the bioecology of the aquatic stages of mosquitoes, a prerequisite for effective control.

Keywords: Culicidae, Bioecology, Physico-Chemical Parameters, El Harrach, Réghaia, Tizi-Ouzou

Cite in this article: Lounaci Z., Medjdoub-Bensaad F., Doumandji-Mitiche B. & Doumandji S. (2022). Bioecology of Culicidae (Diptera: Nematocera) in North Central Algeria. *Bulletin of Pure and Applied Sciences-Zoology*, 41A (1), 86-100.

INTRODUCTION

In Algeria, certain Culicidae species constitute a nuisance and can transmit agents of infectious diseases (Hassaine, 2002). Regular mosquito control campaigns are carried out but their effectiveness, whether chemical or biological, depends on knowledge of the ecology of these insects. Undeniable successes have been obtained against many malaria foci and Algeria is currently considered by the WHO to be in the pre-elimination phase of malaria which can reappear in its epidemic form during climatic circumstances favorable to the development of anopheles (Metge, 1991). The arrival of new vectors such as *Aedes albopictus* in Algeria should also be confirmed (Izri *et al*., 2011). New pathogens such as West Nile virus circulate regularly on the Mediterranean coast, one of the vectors of which is *Culex pipiens* (Durand *et al*., 2005).

It is in this context that knowledge of mosquitoes and their bio-ecology in the region is necessary for their successful control. In ecology the interactions are numerous and complex and like all living beings, Culicidae are attached to their biotope by different links. The ecological preferences of Culicidae should be characterized because they impact their distributions and abundances (El Ouali Lalami *et al*., 2010; El Joubari *et al*., 2014). In Algeria, studies on Culicidae remain fragmented (Berchi, 2000; Hassaine *et al*., 2001) and concern systematics and morphometry (Boudemagh *et al*., 2013; Bendali-Saoudi et *al*., 2013) biology and chemical control (Bendali *et al*., 2001; Boudjelida et *al*., 2005). Our study on the aquatic stages of Culicidae from northern Algeria aimed to draw up an inventory of Culicidian species; document the spatio-temporal dynamics of the main species and research the key ecological factors that can influence these dynamics, in particular for *Cx. pipiens* which is the main source of nuisance.

MATERIAL AND METHODS

Description of study sites

Three regions belonging to the sub-humid, temperate winter bioclimatic stage are prospected for this work. Precipitation is 735 to 758 mm per year there (years 1992-2003) and is generally distributed from October to April with maximums between December and February.

The first, El Harrach (36° 43 'N; 3° 09' E), in the eastern part of Algiers belongs to a vast sub-coastal plain and rises 24 meters above sea level (figure 1).

The second, located 30 km east of Algiers is represented by the coastal marsh of Réghaia (36°46'N.; 3°20'E), corresponding to the estuary of river Réghaia which flows in the Mediterranean. The third is the middle of Sébaou river (36° 44' N; 3° 56' E) located in the Kabylia region, with a length of 110 km from its source in the eastern Djurdjura to its mouth on the Mediterranean sea (Lounaci e*t al*., 2000). Seven above-ground study sites (GE) were selected. The choice of sites took into account the representativeness of Culicidae larvae among a larger group of productive roosts, accessibility, relative sustainability and non-treatment.

In the sub-urban region of El Harrach three artificial settlements have been selected (fig. 1a):
GE1: water tank (36° 43' 11" N, 3° 09' 03" E) 1.16 m in diameter and 0.25 m deep, intended for watering plants and located nearby educational greenhouses of the agronomic institute of El Harrach.

GE2: ornamental pond (0.76 m^2; 36° 43' 15" N, 3° 09' 1" E) located 500 m from the first used as a storage element for watering ornamental plants during water cuts.

GE3: drinking trough (0.5 m^2; 36° 43'10" N, 3° 20' 32" E) located 2 km from the first lodging, near a stable on the station's cattle farm from El Alia.

In the rural area of the Réghaia marsh, three natural sites have been selected (figure 1a):
GE4: semi-permanent brackish swamp (12 m^2; 36° 46' 2" N, 3° 20' 22" E) located on the edge of the Réghaïa marsh. Slow-flowing water is cloudy and polluted by domestic sewage. This lodge is surrounded by relatively abundant vegetation consisting mainly of *Typha angustifolia*. It has a relatively temporary character, characterized by a drying phase in summer and a water phase in winter and spring.

GE5: depression (10.5 m²; 36° 46' 02" N, 3° 20' 24" E) located inside the scrub which is mainly composed of *Olea europaea* olive trees. The water reservoir of this deposit is supplied by water from the water table as well as rainwater.

GE6: permanent freshwater pool (15m²; 36° 46' 45" N, 3° 20' 9" E) with a muddy bottom, located to the immediate northwest of the marsh. It is located on land corresponding to an existing pasture of a few hectares. This roost is surrounded by dense vegetation composed of *Asphodelus microcarpus*, *Juncus acutus* and *Typha angustifolia*. It is supplied by water from the water table and rainwater.

Finally, in the rural environment of Tizi-Ouzou, only one natural lodge has been selected (figure 1b)
GE7: water reservoir (15m²; 36° 44' N, 3° 56' E) located upstream of the Sébaou river. This cottage is surrounded by vegetation made up of cattails. It is supplied by water from the Sebaou River, which permanently receives domestic and industrial wastewater.

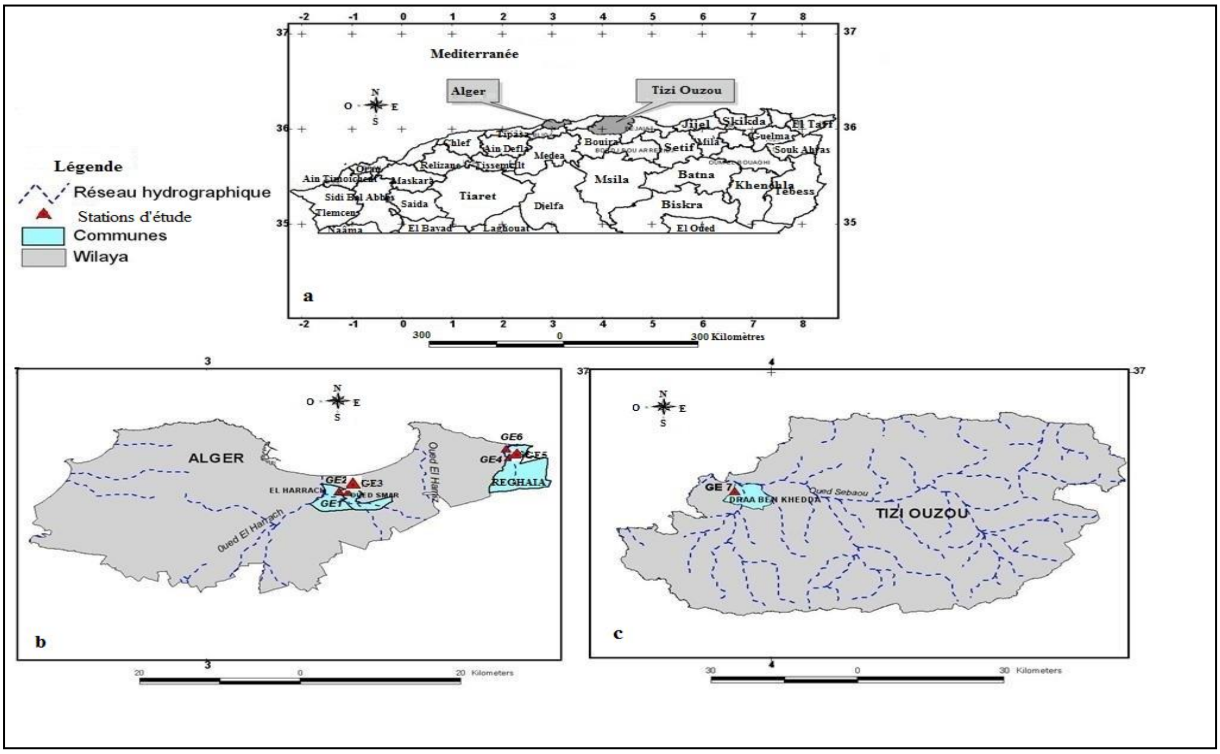


Figure 1: Geographical location of the El Harrach region, the Réghaia marsh, the Sébaou wadi of Tizi Ouzou and location of the study stations (Mutin, 1977). **a:** Lodging GE1, GE2, GE3 of El Harrach; GE4, GE5, GE6 of the Réghaia marsh. **b:** Gîtes GE7 of Oued Sébaou of Tizi Ouzou

Sampling of Culicidian populations

The Culicidian fauna was monitored by 24 samples taken every 15 days over a period of 12 months, from January to December 2003. Samples were taken using the ladle-or-dipping technique (Papierok *et al*., 1975). The ladle with a capacity c (c = 0.5 L) is immersed in water, then moved in a uniform movement, avoiding eddies. Ten ladle shots are thus given in different points of the lodging with a spacing of 1m. In the laboratory, the larvae are sorted by species and by stage then counted. Their determination was made according to Rioux (1958); Senevet et Andarelli (1959) and with the identification software for Culicidae from Mediterranean Africa produced by Brunhes *et al.* (1999). The estimated total size for each stage is calculated using the average number (n) of larvae per ladle stroke, the total roost volume (V) and applying the formula of Croset *et al*. (1976). $P = Vn / c$, the sum of the numbers of all the preimaginal stages of a Culicide species corresponds to its population size in the given roost.

The ecological indices used for the analysis of Culicidae populations are:
- the total richness (S) defined by the number of species found in a sample (Blondel, 1979);

- the relative abundance (A.R.%) defined by the ratio of the number of individuals of a species of Culicidae (Ni) to the total number of individuals of all species (N) obtained in all surveys (Frontier, 1983);

- the Shannon diversity index (H ′) defined by:
$H' = -\sum_{i=1}^{i=S} qiLog2qi$
qi = ni / N is the relative frequency of the category of individuals with respect to i. This index provides information on the diversity of different environments (Frontier, 1985). If the diversity index is high, the environment is very populated with Culicidae and it is favorable to them;

- the equity index (E) defined by the ratio of the observed diversity H' to the maximum diversity H' max (Blondel, 1979) with H 'max = Log2 S. The values of equity vary between 0 and 1. It tends towards zero when almost all the numbers belong to a single species. On the contrary, it tends towards 1, when all the species are represented by the same number of individuals (Ramade, 1984).

Physico-chemical analyzes of water

The physicochemical parameters taken into account and likely to have an impact on the larval development of Culicides are temperature, electrical conductivity, salinity, pH, dissolved oxygen measured using a device such as WTW multiline P4, water level and suspended organic matter. These measurements are carried out regularly in situ in all the deposits at the rate of two samples per month according to the protocols established by Rodier (1984). The organic matter in suspension is measured in the laboratory by filtration then weighing after drying at 150°C (Rodier, 1996). These ecological variables are associated with the total number of individuals of the immature stages of the main species recorded: *Cx. pipiens*, *Cx. impudicus* and *Cs. longiareolata* grouped together for each in a single table. The Spearman correlation test is applied from the overall analysis of the medium, then for each study roost to assess the degree of correlation between the numbers of these species and the abiotic factors studied. This analysis is performed using the xlstat-pro 2012 software (Thioulouse *et al.*, 2004). In addition, a principal component analysis A.C.P. (Thioulouse and Chessel, 1997) to seek to highlight the variables associated with the dynamics of the immature stages (larvae and nymphs) of populations of these species.

RESULTS

Diversity of Culicidae, specific richness and abundance of species

Thirteen species of Culicidae belonging to two subfamilies were inventoried for the entire study (Table 1). The Anophelinae is represented by the single species *An. labranchiae*, the only representative in Mediterranean Africa of the Maculipennis complex. The Culicinae are best represented with 4 genera and 12 species including the genus *Ochlerotatus* with one species: *Oc. caspius*. The genus *Culex* comprises 8 species. *Culiseta* two species *Cs. longiareolata* and *Cs. subochrea*. Finally, the genus *Uranotaenia* only one species *Ur. unguiculata*.

Table 1: Culicidae species inventoried in El Harrach region, the Réghaia marsh and Sébaou wadi of Tizi Ouzou

Family	Sub-family	Tribe	genus	subgenus	Species
Culicidae	Anophelinae	Anophelini	*Anopheles*	*Anopheles*	*Anopheles labranchiae* Meigen, 1818
	Culicinae	Aedini	*Aedes*	*Ochlerotatus*	*Aedes caspius* Pallas, 1771
		Culicini	*Culex*	*Culex*	*Culex mimeticus* Noe, 1899 *Culex perexiguus* Theobald, 1903 *Culex pipiens* Linné, 1758 *Culex theileri* Theobald, 1903
				Barraudius	*Culex modestus* Ficalbi, 1890

				Maillotia	*Culex hortensis* Ficalbi,1889
				Neoculex	*Culex impudicus Ficalbi,* 1890 *Culex territans* Diar, 1905
		Culisetini	*Culiseta*	*Allotheobaldia*	*Culiseta longiareolata* Macquart, 1838
				Culiseta	*Culiseta subochrea* Edwards, 1921
		Uranotaeniini	*Uranotaenia*	*Uranotaenia*	*Uranotaenia unguiculata* Edwards, 1913

In the suburban roosts of the El Harrach region 6 species of Culicidae are collected. *Culiseta longiareolata* (69%) an ornithophile species and *Culex pipiens* (28%) antropophilic species are the most frequent in these types of artificial environments.

The Réghaia marsh is home to 11 species of Culicidae including *Cx. impudicus*, batracophile species recorded in all these natural roosts with a very marked dominance (44%) and seems to have a preference for the GE5 roost (Table 2). In this scrub, the formation of a depression around the olive trees seems favorable and thus constitutes a favorite breeding ground for this species. It is followed by *Cx. pipiens* with 28.36% whose nuisance is strongly felt in this environment. Also noteworthy is the presence of *An. labranchiae* in particular in the GE6 deposit (45%). This species seems to have a preference for natural larval sites rich in vegetation composed in particular of *Typha angustifolia*. Its presence in the environment remains a significant health risk, given that it is the potential vector of *Plasmodium falciparum*, the causative agent of malaria. In the Middle Sébaou river region of Tizi-Ouzou, only 4 species are collected, including *Cx. pipiens* with 86% constituting the bulk of the catches.

Table 2: Numbers and relative abundance (RA %) applied to the preimaginal stages of Culicide species in the study sites

Stations	**El Harrach**		**Reghaia marsh**										**Oued Sébaou**	
Larval sites	GE1		GE2		GE3		GE4		GE5		GE6		GE7	
Species	Ni	AR%	Ni	AR%	Ni	AR%	Ni	Ni AR%	Ni	AR%	Ni	AR%	Ni	AR%
Anopheles labranchiae	12	0.11	0	0	0	0	0	0	0	0	1005	44.61	46	0.58
Aedes caspius	0	0	0	0	1	0.33	0	0	0	0	0	0	0	0
Culex pipiens	3418	33.22	0	0	229	76.59	11280	54.73	0	0	0	0	6798	86.03
Culex mimeticus	0	0	0	0	0	0	27	0.13	0	0	443	19.66	0	0
Culex perexiguus	0	0	0	0	0	0	187	1.41	0	0	120	5.33	0	0
Culex modestus	385	3.74	0	0	0	0	960	4.7	0	0	0	0	514	6.50
Culex impudicus	0	0	0	0	0	0	506	2.48	16537	96.53	561	24.15	544	6.88
Culex territans	0	0	0	0	0	0	80	0.39	166	0.97	0	0	0	0
Culex hortensis	0	0	0	0	0	0	27	0.13	229	1.33	1	0.04	0	0
Culex theileri	0	0	0	0	0	0	80	0.39	42	0.24	0	0	0	0
Culiseta longiareolata	6475	62.93	2595	100	68	22.74	6853	33.55	83	0.49	0	0	0	0
Culiseta subochrea	0	0	0	0	1	0.33	0	0	0	0	0	0	0	0
Uranotaenia unguiculata	0	0	0	0	0	0	427	2.09	75	0.44	140	6.21	0	0
Somme Ni	10290	100	2575	100	299	100	20327	100	17132	100	2253	100	7902	100

Shannon Diversity Index and Equitability Index

The Shannon diversity index shows values varying between 0.29 bits for the GE5 deposit and 1.96 bits for the GE6 deposit (Table 3). The variability in diversity over the year is quite low because each sample is characterized by the dominance of a small number of species. The values of the Equitability index are close to 0 in the study sites except forGE1 and GE6, reflecting an imbalance between the numbers of species present.

Table 3: Total wealth (S), Schanon - Weaver Diversity Index (H '), Maximum diversity index (H 'max), Equidispensing index (E) of Culicidae in the study stations.

Stations	**El Harrach**	**Reghaia marsh**				**Oued Sébaou**
larval sites	GE1	GE3	GE4	GE5	GE6	GE7
H′	1.14	0.83	1.61	0.29	1.96	0.75
S	4	4	10	6	6	4
H′ max	2	2	3.33	2.59	2.59	2
E	0.57	0.42	0.48	0.11	0.76	0.38

Phenological distribution of the main species

The population dynamics of a few identified Culicidae species are monitored in the various study sites. The species taken into consideration are those frequent and common in more than four study sites (Table 4, **Appendix 1**). This is the case with *Cx. pipiens*, *Cx. impudicus* and *Cs. longiareolata*.

The months of May, June, September and October alone account for nearly 90% of the catches for these species. Their phenological cycle seems to be completely covered by the trapping campaign (Figure 2).

Culex pipiens is listed in the sites, GE1, GE3, GE4 and GE7. The first larval generation appeared on February 8 in the ornamental pond GE1 of El Harrach and on the 23 of this month in the edge of Réghaia marsh GE4 (Figure 2a). Low numbers of hatchings follow one another on these same sites until the beginning of April when the productivity of 2 other breeding sites begins, GE3 from El Alia, and GE7 from Sébaou River. At the beginning of May all the sites shelter the larvae of different stages. Indeed, the numbers increase gradually and become very important at the end of May and / or the beginning of June. This species will persist until early July. During the summer season all the lodgings are negative. In the edge of the GE4 marsh and the Sébaou River GE, climatic conditions determine a drying period which results in the absence of larval and pupal stages. On September 20, the first rains contributed to the emergence of new generations. At the beginning of October, the numerous hatchings concern these sites. Then the numbers gradually decrease. In fact, only a few larvae, particularly of the older stages, are counted.

Culex impudicus is only present in the natural roosts of the Réghaia marsh and Sébaou River. In the GE5 scrub, its development cycle covered a continuous period of eight months (end of March-beginning of November). Its first appearance is reported in March. During the spring period, the outbreaks multiply. The maximum load is observed in June (Figure 2b). Three hatching peaks were separated. The larval growth period is two months in spring, three months in autumn and much shorter in summer. At the edge of the GE4 marsh, this species only developed for three months of the year, in February, October and November. The highest number is recorded in early November. In the GE6 pond and the Sébaou River, GE7 two generations have developed, one in spring and the other in autumn. At the latter site, the activity of *Cx. impudicus* extends from May to June. It reappears in early October and lasts until November. The species predominates in May.

Culiseta longiareolata is found in the sites GE1, GE2, GE3 of El Harrach and GE4, GE5 of the Reghaia marsh. With the exception of the summer season, its larvae are harvested throughout the GE1 roost, while noting a clear winter decline. This species exhibited four peaks of hatching for the first two roosts and three peaks of hatching at barn GE3 and the edge of marsh GE4 (Figure 2c). The life cycle is interrupted in summer due to high temperatures for one and the drying up of the roost for the other, not to resume until the beginning of October. *Culiseta longiareolata* is abundant mainly in spring and autumn. At the level of the GE5 scrub, the growth of the only generation produced lasted about two weeks during the month of September. This roost does not seem to be a favorable place for the development of larvae of this species where *Cx. impudicus* remains dominant throughout the year.

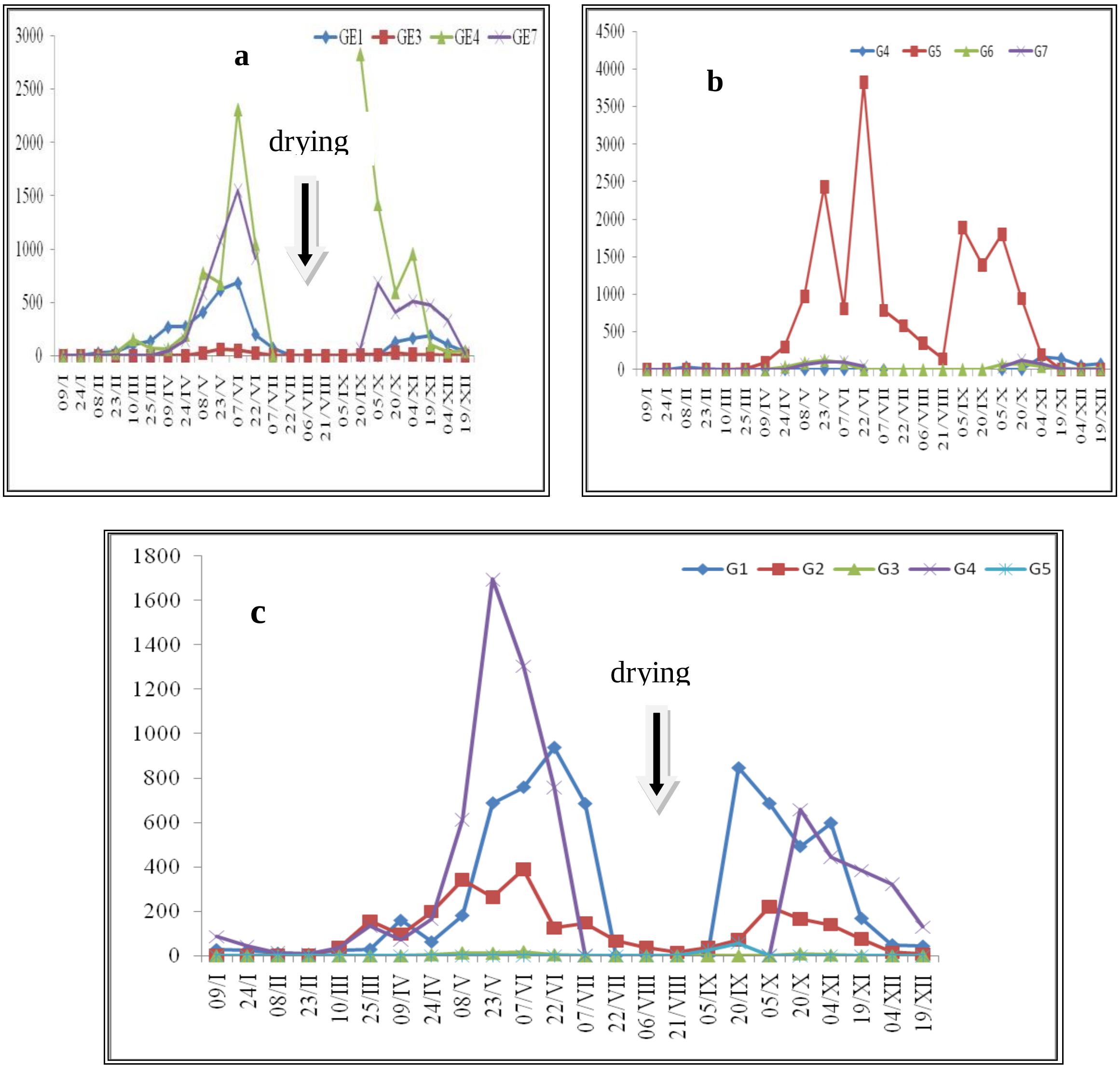


Figure 2: Variation over time of larval and nymphal numbers in study sites during. **a:***Cx. pipiens*; **b:***Cx. impudicus*; c: *Cs. longiareolata*

Influence of physico-chemical parameters on the numbers of *Cx. pipiens*, *Cx. impudicus* and *Cs. longiareolata*

The relationship between *Cx. pipens*, *Cx. impudicus* and *Cs. longiareolata* and the six physicochemical parameters is analyzed by the global study of the deposits corresponding to each species. The observed correlations are summarized in Table V and Figure 3.

The preimaginal numbers of *Cx. pipiens* ($r = 0.425$; $p < 0.05$), from *Cx. impudicus* ($r = 0.378$; $P < 0.05$) and *Cs. longiareolata* ($r = 0.303$; $P < 0.05$) are positively related with temperature. The coefficients of determination R^2 = 18%, 14%, 9% respectively explain in percentage the variations of the larval numbers of these species by those of the temperature. These coefficients of determination, well below average, mean that temperature alone does not explain the variations in larval numbers of these species. These would be subject to the influence of other physicochemical parameters.

Table 5: Spearman's correlation coefficient showing the relationships between the numbers of eimaginal stages of *Cx. pipiens*, *Cx. impudicus*, *Cs. longiareolata* and physico-chemical parameters

physico-chemical parameters larval sites	**Hauteur (cm)**	**Temperature (°C)**	**pH**	**Salinity (g/l)**	**Conductivity (µS.cm^{-1})**	**Dissolved oxygen**	**Organic matter**
CE1, GE3, GE4, GE7)	**C*x. pipiens***						
	-0.365	0.425	0.331	0.351	0.673	0.264	0.531
	(0.001) *	(0.000) *	(0.002)*	(0.001) *	(0.000) **	(0.014) *	(0.000) **
(GE4, GE5, GE6, GE7)	***Cx. impudicus***						
	0.308	0.378	-0.293	-0.082	0.311	-0.130	0.523
	(0.004)*	(0.000)*	(0.006)*	(0.450)	(0.004)*	(0.231)	(0.000)**
(G1, G2, G3, G4, G5)	***Cs. longiareolata***						
	-0.103	0.303	0.295	0.150	0.520	0.088	0.356
	(0.401)	(0.012)*	0.015)*	(0.221)	(0.000)**	(0.474)	0.003)*

*** : r** significant at the 5% level **;** **** :r** highly significant at the 5% level

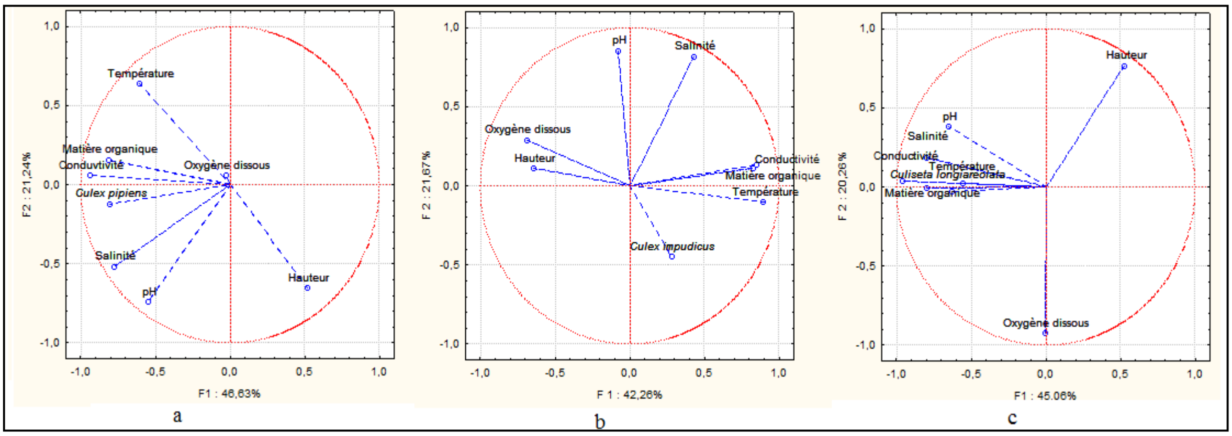
If we refer to the PCA established in Figure 3a, other elements contribute to account for these variations. For *Cx. pipiens*, this analysis shows a large part of the variability taken from the first two axes F1 and F2which respectively summarize 46.63% and 21.24% of the total information. Indeed, the variation in the numbers of *Cx. pipiens* according to the conductivity and organic matter contents are explained respectively by 45% (r = 0.673; P <0.05) and 28% (r=0.531; P <0.05). This variation seems to be less influenced by salinity (R^2=12%), pH (R^2=11%) and dissolved oxygen contents (R^2=7%). The conductivity, which testifies to mineralization of deposit water and organic matter, seems to be the most positively associated with the numbers of *Cx. pipiens*. These two parameters therefore partly favor the development of *Cx. pipiens*. The water depth is correlated with the population size negatively 13% (r=-0.365; P<0.05).

The variations in the numbers of *Cx. impudicus* (Table5, Figure 3b) according to organic matter is explained by 45% (r=0.523; P<0.05). This variation does not seem to be under the influence of the conductivity R^2 = 10%. Water depth (r=- 0.308; P<0.05) and pH (r=- 0.293; P<0.05) are negatively correlated with population sizes, while salinity and dissolved oxygen do not appear to have an effect on the larval numbers of the species. This assumes that the organic matter therefore partly promotes the proliferation of *Cx. impudicus*.

The workforce of *Cs. longiareolata* (Table 5, Figure 3c) are positively correlated with conductivity (r=0.520; P<0.05), organic matter (r=0.356; P<0.05) and pH (r=0.295; P<0.05). Water depth, salinity and dissolved oxygen do not appear to have an effect on the larval numbers of the species. Moreover, this correlation although it is positive, it is significant only in the case of conductivity. This therefore indicates that this factor partly favors the development of the larval numbers of this species.

It would seem that the spatio-temporal variations of the larval numbers of *Cx. pipiens*, from *Cx. impudicus* and *Cs. longiareolata*, could not be attributed only to the mesological parameters (organic matter and/or conductivity) studied.

While temperature alone does not explain the variations in larval densities at these sites, this does not seem to be negligible, as it can modify the physicochemical characteristics of the water (particularly in spring).



a b c

Figure 3: Correlation circles of the preimaginal numbers and the physico-chemical parameters according tofactorial axes 1 and 2 of the PCA. **a:***Cx. pipiens*; **b:***Cx. impudicus*; **c:***Cs. longiareolata.*

DISCUSSION

Thirteen Culicidae species, among the 48 recorded in Algeria (Brunhes *et al.*, 2000), were collectedduring our surveys. This richness lies in the diversity of the biotopes offered to the development of Culicidae. In the Reghaia Marsh and the Sébaou River, the *Culex* genus constitutes 78.41% and 99.14% of the harvests respectively. On the other hand, in the region of El Harrach it is the *Culiseta* genus which predominates with 56.52%.Among the species recorded, *Cs. Longiareolata* (69.31%) and *Cx. pipiens* (27.66%) are the most abundant species in the suburban part of El Harrach. In the rural setting of the Reghaia marsh, *Cx. impudicus* with 44.26 % and *Cx. pipiens* with 28.36 % show the bulk of the catches. The latter (A.R. = 86.03%) largely dominates in the Sebaou river.

Thus, *Cx. pipiens* is a species distributed throughout the study regions and frequently associated with human activities. Merabti *et al.* (2021) classified *Cs. longiareolata* and *Cx. pipiens* among species with a very wide distribution in Mediterranean Africa. In northeast Algeria, the same number of specimens was inventoried by Boudemagh *et al*. (2013) in the Collo region. These authors have shown that the frequency of *Cx. pipiens* is highest in the sub-humid and humid to mild winter stages and totals more than 50% of the Culicidal fauna captured. Messai *et al.* (2010) inventoried over a ten-month period, twelve Culicidae species in the Mila region, belonging to 2 subfamilies: Anophelinae and Culicinae.In this locality belonging to the semi-arid bioclimatic stage, *Cx. pipiens* and *Cs.longiareolata* are the most abundant. On the other hand, in the same bioclimatic stage of the Constantine region, only six species of Culicidae are recorded over a period of two years (Berchi, 2000). This author emphasizes the dominance of *Cx. pipiens* in different urban and peri-urban environments In North-West Algeria (Tlemcen), Hassain (2002) noted over the same sampling period, the presence of 20 Culicidae species belonging to two sub-families: Anophelina and Culicinae in different roosts natural and artificial. *Culiseta longiareolata* (24.41%) and *Culex pipiens* (22.26%) come first in catches. In the Highlands (Tebessa) of the arid bioclimatic stage, the work of Bouabida *et al.* (2012) identified 9 Culicidae species belonging to the Culicinae subfamily, of which the above-mentioned species constitute the bulk of the harvests.

In addition, the presence of *An. labranchiae* in all the study regions agree with the observations made in Morocco by Himmi *et al.* (1998), Trari *et al.* (2002). Those authors report that this species likes rivers as well as marshy areas. Of the three study regions, it is the Réghaia marsh that hosts the greatest number of Culicidae with a relative abundance equal to 65% against only 21.64% and 12.97% for El-Harrach and Sébaou River. It goes without saying that this marsh is very rich in different roosts (lake, scrub and ponds) and in dense and diversified vegetation cover mainly composed of *Typhaangustifolia* (GE4 and GE6) and *Olea europaea* (GE5).

Among the abiotic factors studied, temperature may favor the development of preimaginal populations of *Cx. pipiens*, because in all the roosts studied, the lowest larval numbers were observed in winter. The result do not corroborate those of Subra (1973) witch reports that a decrease in water temperature is at the origin of the lengthening of the life of the larval stages, thus explaining the appearance of high preimaginal densities. In our study, the development cycle for this species is interrupted during this season in the first months of the year which correspond to the winter season. This arrest of development in open-air deposits has been observed by several authors (Bouguera *et al.* 2017; Hamaidia and Berchi 2018). Sinegre (1974) and Gabinaud (1975), report that temperature, salinity and quantity of food are involved in the process of regulating the rate of development of *Oc caspius* larvae. These authors have also demonstrated in the Camargue the existence of a minimum thermal threshold which makes the *Oc caspius* larvae disappear. From November to March; while *Ochlerotatus detritus* continues to develop throughout the winter. However in Morocco, Elkaiem (1972) has shown that the arrest of development observed in France did not take place in the deposits of Rabat. Nevertheless, the presence in El Harrach, and in the Reghaia marshes of *Cx. pipiens* in GE1, GE4 during the winter season raises many questions about the influence of temperature on the development cycle. These results on the presence of larvae of this species in winter in outdoor biotopes corroborate the work of Dancesco *et al.* (1975) and Berchi *et al.* (2012). The authors report that the presence of significant vegetation in the roosts buffers temperature fluctuations, thus constituting particular microclimates, which can favor the continuous development of the species or at least its maintenance in the roost during the cold season.

Conversely, the spring period is associated with a strong proliferation of the pre-imaginal stages. The larval evolution observed during this period is also due to the food available in the roosts. According to Gaschen (1932), larval development is faster when the water temperature increases. It conditions the speed of development of *Cx.pipiens*, acting mainly on the duration of larval development and to a lesser extent on the duration of pupal development. This influence of temperature on the rate of larval development is also studied by Bar-Zeev (1958) on *Aedes aegypti*. This author reports that larval development is inhibited not only by low temperatures, but also by high temperatures. For Macan (1981), any heating or cooling of the environment can disrupt the development cycle of several aquatic insects, especially in Culicidae (El Kaïm 1972). Moreover, Subra (1973) points out that in addition to the influence of ecological factors on larval development, there is the attractiveness of gravid females to roosting which may explain the presence of larval stages.

Regarding the seasonal activity of *Culex pipiens*, the bibliographic data seem contradictory. Indeed, Kirkpatrick (1925) does not mention a period of larval activity for this species while Gaud (1952) reports a spring explosion. A year later, this last author considers it autumnal. Other regional studies report maximum summer abundance for this species (Hassaine, 2002; Berchi *et al.*, 2012). Besides temperature, other abiotic factors can influence the establishment and preimaginal development of *Cx.pipiens*. The demographic kinetics of this species also depend on conductivity and organic matter. Decomposition of the latter promotes mineralization by increasing conductivity (Sinegre, 1974). The presence of this species in waters particularly rich in organic matter has been reported by Louah *et al*., (1995) and El Ouali Lalami *et al.* (2010). The numbers increase to reach maximum values, and then decrease when resources become insufficient. The conductivity thus seems to have an action on the development and the distribution of *Cx. pipiens* in different biotopes (Metge and Hasaine, 1998). The increase in hopper numbers for *Cx. pipiens* is only recorded for conductivity values greater than 1014 $\mu S.m^{-1}$. The high values of conductivity associated with high temperatures lead to the disappearance of the peimaginal stages of the deposits. Our results corroborate those of Benkhalfate-El Hassar (1991). This author reports that conductivity can act either as a limiting factor when it is high, or as a stimulating factor at the outbreak level.

The pH varies very little in the suburban deposits of El Harrach, on the other hand in the rural lodges; the variations of this factor seem to be influenced by the seasons. In these deposits, the pH is generally higher in spring and sometimes even in summer in the Réghaia marshes and Sébaou River. These two seasons coincide with the period of strong chlorophyll assimilation of the vegetation located on the edge of these roosts and of the aquatic flora (filamentous algae of the genus *Spirogirasp*), using the carbon dioxide available particularly during the day and increasing the pH. De Alwis and Munasinghe (1971) find that the pH plays an important role in acting on the control of the larval development of *Cx. pipiens*.Correlations of larval numbers with salinity indicate that the species frequents not only freshwater, but also relatively high salinity environments. This is the case of the GE4 roost where the salinity can reach 11 mg/l.

In addition to temperature, larval development time is related to variations in water level and the length of the drying period for some breeding sites. Thus in summer, the absence of larvae and nymphs in the GE4 and GE7 roosts is linked to the temporary nature of these biotopes. Rainwater intake is infrequent, given the significant water losses through evapotranspiration and infiltration. These deposits are characterized by drying periods of three months. Prolonged assecs are a handicap to larval development (Handaq and Boumezzough, 1999). In the GE7 deposit of Sébaou River, the rapid regression of the body of water during this period causes the larvae to be trapped in small peripheral water collections where predation can play a determining role. It is mainly due to Heteroptera and Aquatic Coleoptera which are very abundant in the environment. Competition for food could also play an important role in the development of larval stages, as retarded larvae are always observed, the growth of which could be blocked by lack of food or by the mass effect resulting from the intraspecific competition (Moore and Witacre, 1972). Replenishment, triggered by the autumn rains, causes the eggs to hatch and the appearance of new generations. After each rise in the water level, the species experiences an increase in numbers, especially the L1 and L2 stages, caused by the massive hatching of the eggs. Dissolved oxygen appears to have no effect on larval development.

Regarding the seasonal activity of *Cx. impudicus*, our results agree with data from Senevet and Andarelli (1959). Those authors claim that the larvae can be seen most of the year, but mostly from May to November. However Himmi *et al.* (1998) report that the species adopts an autono-wintero-spring development. In the more stable GE5 and GE6 roosts the high summer mortalities of the immature stages of *Cx. impudicus* are due on the one hand to a decrease in the volume of water which generates a high concentration of salts resulting in a high conductivity, on the other hand to the abundance of filamentous algae of the genus *Spirogira* on the surface of water which impedes the respiration of larvae. In autumn, rainwater supplies dilute the salts and promote the development of the pre-imaginal stages. The species seems to prefer fresh waters that are well mineralized and rich in organic matter. This same observation is invoked by El Joubari et *al*. (2014) who find that the species prefers slightly brackish and well oxygenated fresh water.

Culiseta longiareolata shows seasonal variability in its development time. The species is present year round in some man-made and natural sites and abundant in spring and fall. Our results corroborate those of Boudemagh and *al.* (2013) who report a continuous autono-winter-spring development of the species in urban and rural sites in northeastern Algeria (Collo). Old data on the seasonal larval activity of this species is due to Gaud (1953) who considers it to be winter. Senevet and Andarelli (1959) report a variation in the annual cycle from one region to another: in the Tell, the species is present all year round, with abundance in spring; in the highlands, it abounds especially in autumn, while in the Saharan regions, it is rather winter and spring. *Culiseta longiareolata* is a species of great ecological valence, able to withstand the abiotic conditions of different environments, namely deposits whose water is well mineralized and rich in organic matter, moderately salty to brackish (GE4) and moderately mineralized and oxygenated (GE1, GE2). Brunhes *et al.* (2000) find that the larval breeding sites of the species are of very varied types where the water can be fresh and brackish.

In view of the parameters studied, a deposit must have water rich in organic matter and well mineralized to allow *Culex pipiens*, *Culex impudicus* and *Culiseta longiareolata* to develop rapidly and reach high numbers. But for these species the spatio-temporal variations in their aquatic ecophase could not be attributed solely to these physicochemical parameters, as Trari (1991) and Chlaida and Bouzidi (1995) have already pointed out. Other mesological factors such as chlorides and ammoniacal nitrogen as well as anthropogenic activities (domestic and industrial discharges) carried out in certain sites (GE4, GE7) may intervene to account for these variations, particularly in *Culex pipiens* (Berchi *et al.*, 2012). It is therefore important that rapid remediation measures be undertaken at these two sites if the incidence of these nuisances is to be reduced in these regions.

ACKNOWLEDGEMENT

We sincerely thank the staff of the hunting center of Réghaia and the regional plant protection station of Tizi Ouzou for their collaboration and their help in the field.Collecting Culicidae larvae would not have been possible without their help.

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Table 4 : (Appendix 1) Spatio-temporal variation in numbers of immature stages (larvae and nymphs) of Culicidae species in the El Harrach, Réghaia marsh and Tizi Ouzou wadi in 2003.

Gîte	**Species**	**09/I**	**24/I**	**08/II**	**23/II**	**10/III**	**25/III**	**09/IV**	**24/IV**	**08/V**	**23/V**	**07/VI**	**22/VI**	**07/VII**	**22/VII**	**06/VIII**	**21/VIII**	**05/IX**	**20/IX**	**05/X**	**20/X**	**04/XI**	**19/XI**	**04/XII**	**19/XII**	**Total**	**Fréquence**
El Harrach	*An. labranchiae*	0	0	0	0	0	0	0	0	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0,09
	Ae. caspius	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0,01
	Cx. pipiens	0	0	23	33	98	135	267	273	435	672	730	222	71	0	0	0	0	10	9	155	175	200	103	36	3647	27,66
	Cx.modestus	0	0	0	0	0	0	2	10	72	152	107	42	0	0	0	0	0	0	0	0	0	0	0	0	385	2,92
	Cs.longiareolata	27	23	13	6	61	185	255	265	536	962	1167	1067	832	65	35	14	35	918	907	668	740	243	64	50	9138	69,31
	Cs. subochrea	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0,01
Marais Réghaia	*An. labranchiae*	0	0	0	0	0	0	0	0	25	147	154	138	27	0	0	0	37	132	97	138	99	11	0	0	1005	2,53
	Cx. pipiens	0	0	0	24	154	66	63	196	774	677	2306	1046	0	/	/	/	/	2824	1419	595	954	102	38	42	11280	28,36
	Cx. mimetucus	0	0	0	0	0	0	0	0	11	54	79	37	9	7	4	0	0	0	76	96	64	33	0	0	470	1,18
	Cx. perexiguus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	18	24	57	71	74	20	7	307	0,77
	Cx. modestus	0	0	0	0	0	0	0	0	128	259	186	62	0	0	0	0	0	0	41	118	92	69	5	0	960	2,41
	Cx. impudicus	0	0	36	17	0	7	96	337	1059	2556	894	3824	788	585	354	147	1892	1394	1864	1022	417	165	64	86	17604	44,26
	Cx. territans	0	0	0	0	0	0	17	45	43	61	0	0	0	0	0	0	0	0	0	40	27	9	4	0	246	0,62
	Cx. hortensis	0	0	0	0	0	0	0	0	19	73	47	14	0	0	0	0	0	0	28	55	21	0	0	0	257	0,65
	Cx. theileri	0	0	0	0	0	0	0	0	0	31	30	8	0	0	0	0	0	0	0	0	0	0	0	0	69	0,17
	Cs. longiareolata	85	42	13	7	34	134	71	163	613	1696	1305	757	0	0	0	0	25	58	0	657	443	383	322	128	6936	17,44
	Ur. unguiculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	97	125	192	122	72	642	1,61
Oued Sebaou Tizi Ouzou	*An. labranchiae*	0	0	0	0	0	0	0	0	0	34	12	0	/	/	/	/	/	0	0	0	0	0	0	0	46	0,58
	Cx. pipiens	0	0	0	0	0	0	42	145	586	1073	1552	917	/	/	/	/	/	65	681	405	512	473	329	18	6798	86,03
	Cx. modestus	0	0	0	0	0	0	0	14	32	64	62	0	/	/	/	/	/	0	33	93	125	72	19	0	514	6,50
	Cx. impudicus	0	0	0	0	0	0	0	0	67	102	98	42	/	/	/	/	/	0	36	121	72	6	0	0	544	6,88

(/) Summer drying