RESEARCH ARTICLE

CULICINE MOSQUITOES (DIPTERA: CULICIDAE) COMMUNITIES AND THEIR RELATION TO PHYSICOCHEMICAL CHARACTERISTICS IN THREE BREEDING SITES IN EGYPT

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ABSTRACT

Mosquitoes have diverse species and global distribution. Most freshwater bodies support different mosquito species breeding. The physicochemical characteristics of mosquito breeding sites may influence culicine species distribution and their abundance. This study aimed to determine culicine species communities and their abundance in two rural sites and one urban breeding site in Egypt considering physicochemical characteristics of breeding places. These areas were Al-Beshlawy drainage canal (Giza), El-Khartoum irrigation ditch (Beheira), and Tanta man-made ground hole (Gharbia), respectively. The measured physico-chemical parameters were temperature, pH, salinity, turbidity, dissolved oxygen, and nitrite. Diversity indices (recorded number of species, diversity, equitability, and concentration of dominance) of mosquitoes were also calculated. The results showed that six culicine species were identified in the tested three breeding sites. These were *Culex pipiens*, *Cx. univittatus*, *Cx. antennatus*, *Cx. quinqueifasciatus*, *Cx. perexiguus*, and *Culiseta longiareolata*. All species are native to the Egyptian fauna. In all tested urban and rural breeding sites, *Cx. pipiens* was considered eudominant. Bray-Curtis dissimilarity in the culicine community between the tested sites ranged between 0.03 and 0.12. This dissimilarity may be attributed to the absence of certain species in some sites, as well as the significant difference in the abundance of *Cx. pipiens* and *Cs. longiareolata* among the sites. Water salinity and dissolved nitrite content differed significantly among the breeding sites. The multiple regression analysis between the identified culicine species and the physicochemical parameters showed that salinity, nitrite content, turbidity, and pH are considered key factors to predict some culicine species in water bodies.

INTRODUCTION

Vector-borne diseases account for more than 17% of all infectious diseases. So, vectors are responsible for more than 700000 deaths yearly[1]. Insects represent most vectors of diseases among humans and their domestic animals[2]. Mosquitoes are the primary vectors of serious diseases including malaria, filariasis, dengue fever, rift valley fever, yellow fever, Zika fever, chikungunya fever, Japanese encephalitis, and West Nile fever among humans[3-5].

In general, twenty-nine mosquito species belong to *Anopheles*, *Culex*, *Culiseta*, *Ochlerotatus*, and *Uranotaenia* genera were native to Egypt[6-10]. They infested all rural and urban areas[11-14]. Mosquitoes have great diversity and abundance worldwide and are in close contact with a man and his domestic animals[15]. They can breed in any type of natural or artificial aquatic habitats, including ponds, marshes, flood-waters, storm drains, old tires, and water in tree holes. Mosquito larvae breed in habitats with a wide range of physicochemical characteristics, like salinity, turbidity, nitrate, dissolved organic matter, water temperature, hydrogen ion concentration, dissolved oxygen (DO) values, and sunlight[16].

The physicochemical characteristics may influence oviposition, survival, and distribution of mosquito species. Each species has its specific oviposition and breeding sites. The breeding water of *Aedes* sp. exhibited higher oxygen content than those of *Culex* and *Anopheles*[17]. *Cx. pipiens* complex may withstand different degrees of water pollution, while *Culiseta longiareolata* aggregates in high salinity and alkaline water[18,19]. The temperature has a great effect on the biology of *Cx. pipiens* larvae[20]. Thus, monitoring programs and regular surveys on water bodies may provide essential information about the suitability of breeding sites to diverse numbers of mosquito species. The agricultural activities and urbanization such as rice cultivation,

watering, and fish farming have led to spread of various species of mosquitoes[21]. Though some studies have examined several culicine breeding sites and their physicochemical characteristics in some Egyptian Governorates[13,14,22]; fragmentary information is available about other water bodies and Governorates in Egypt. Thus, the present study aimed to explore species communities of culicine mosquitoes and their relative abundance in correlation to physicochemical characteristics of mosquito breeding habitats in rural (Giza and Beheira Governorates) and urban (Gharbia Governorate) areas in Egypt. The results could help to predict culicine species communities in similar sites based on their identified physicochemical parameters. Precise knowledge of the mosquito ecology and identification of mosquito larvae species is of great importance to improve vector control programs[17,23].

MATERIAL AND METHODS
Study areas and sampling sites
Mosquito larvae were collected from rural and urban breeding habitats in three Egyptian Governorates (Figure 1). The rural mosquito breeding sites were in Giza Governorate (Abu Rawash Village) and Beheira Governorate (El-Khartoum Village). The urban breeding site was in Gharbia Governorate (Tanta University campus). These mosquito breeding sites were selected mainly according to geographic basis.
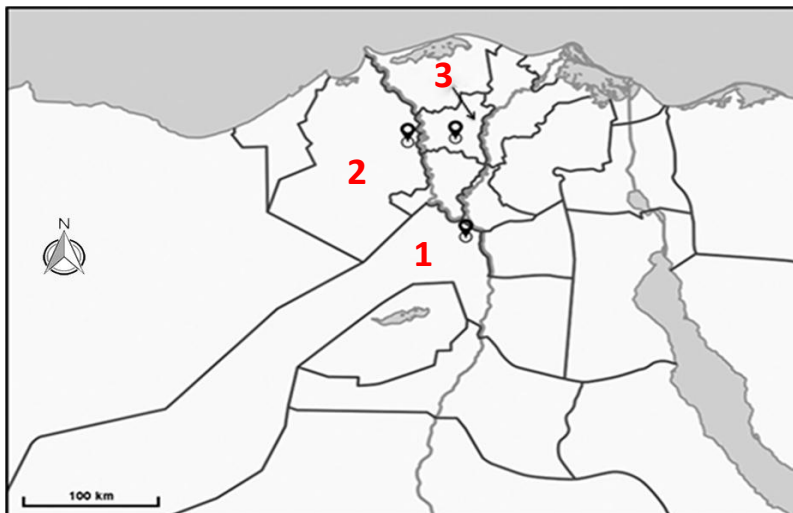

Figure 1: Map of mosquito sampling sites in Giza (**1**), Beheira (**2**), and Gharbia (**3**) Governorates, Egypt.

Abu Rawash village is an archaeological area (ruined pyramids of Djedefre), located 8.0 kilometres north of the International Tourist Giza Governorate. This small village is considered a rural area where the inhabitants are mainly involved in agriculture, livestock husbandry, snake hunting, and tourism handwork industry. Mosquitoes were collected from Al-Beshlawy open drainage canal (located 30°2'54.157"N latitude and 31°5'56.162"E longitude) with a width of about 2-7 m and a depth of 2 m. Its length is about 3.05 km. The water surface is dominated by water hyacinths and algae. Drainage canal is much polluted with sewage and industrial waste, surrounded by residential areas, fodder factories and breeding domestic animals farms (Figure 2A).

El-Khartoum village (Beheira Governorate) is also considered as a rural area located west of the Nile Delta. Mosquitoes were collected from an irrigation ditch (located 30°33'21.116"N latitude and 30°39'53.319"E longitude) with 1.0 m width and 50 cm depth. Its length is about 1.5 km. The water-body contains agricultural wastes, as being surrounded by agricultural areas (alfalfa and castor trees) and domestic animals breeding farms (Figure 2B).

The convention campus of Tanta University site is located in the centre of Tanta City, Gharbia Governorate. This area is an urban site that encompasses various sectors of workforces including shops, restaurants, hospitals service, and faculties. Mosquito samples were collected from a stagnant man-made ground hole near to Faculty of Science (located 30°48'5.339"N latitude and 30°59'36.114"E longitude) with a width of 1.0 m and depth of 1.0 m. It contains rain and drainage water (Figure 2C).

Figure 2: Landscape photographs of surveyed mosquito habitats: (**a**) Al-Beshlawy drainage canal in a rural agricultural area of Abu Rawash, (**b**) El-Khartoum irrigation ditch in a rural settlement area, (**c**) an urban man-made ground hole near Tanta University campus.

Larval and water sampling
Mosquito larval sampling was conducted during June – August 2017. In each site, mosquito larvae were collected by standard 350 mL plastic dipper according to the protocol of WHO[24]. After each dipper, the collected larvae were transferred to glass jars with enough air for respiration. Concurrently, water samples were collected in glass bottles for physicochemical analysis. Five dips were taken from Al-Beshlawy drainage irrigation canal and El-Khartoum irrigation ditch breeding sites at a distance of 200 m from each sample location. In the man-made ground hole, samples were sequentially taken at once. Containers were labelled and transported to the laboratory after each sampling.

Culicine identification, classification, and ecological parameters
To identify the collected mosquito' species, hundred living third instar larvae were identified per dip/site (N = 500). Larvae

were examined by a compound light microscope Optic 10 lab (Ray wild limited company, Germany). Larvae were identified by morphological characteristics described in Harbach's pictorial key[25]. Several calculations were made to have Bray-Curtis' dissimilarity, recorded number of species, their diversity, equitability, and concentration of dominance in different sites. Bray-Curtis dissimilarity (BC_d) was determined according to the equation of Bray and Curtis[26]:

$$BC_d = \frac{\sum |n_i - n_j|}{\sum (n_i + n_j)}$$

Where n_i and n_j are the numbers of individuals counted of species in sites i and j, respectively.

Species diversity and equitability (E) were calculated as described in Mwangangi et al.[27] using Shannon-wiener diversity index (H′) according to the following equations:

$$H' = -\sum [p_i * ln(p_i)]$$

Where P_i is the number of individuals of species i divided by the total number of all species.

$$E = H'/ln(S)$$

Where S is the total number of species

The concentration of dominance (CD) was calculated as described by Thakur and Khare[28] according to the equation:

$$CD = \sum \left(\frac{n_i}{N}\right)^2$$

Where n_i is the number of individuals of species; and (N) is the total number of all species.

Physicochemical analysis of water samples

Maximum and minimum air temperature after meteorological data was 29-43ºC, 26-37ºC, and 17-25ºC in Giza, Beheira, and Gharbia Governorates, respectively. Water temperature was calculated according to the equation of Preud'homme and Stefan[29]:

$$T_w = 5.0 + 0.75\, T_a$$

Where T_w is the water temperature, while T_a is the air temperature.

The water pH was measured using a pH meter (model: 6173 pH, JENCO Instruments Inc., San Diego, CA, USA). Salinity percentage and turbidity, nephelo-metric turbidity unit, (NTU) were measured using a conductivity meter HI 2300 and turbidimeter HI 98703, respectively (Hanna Instruments Inc., Smithfield, RI, USA). The DO content (mg/L) in water was measured by standard methods of American Public Health Association[30]. In brief, a volume of 2 mL $MnSO_4$ solution and alkaline iodide reagent was added to 300 mL water sample. The mixture was re-stoppered to completely exclude air bubbles and mixed several times. After precipitation, the precipitate was contacted with seawater for 10 minutes. After it settled down, the clear supernatant was produced; the stopper was carefully removed and immediately 2 mL of concentrated H_2SO_4 was added then the bottle was stoppered and mixed by gentle inversion to make a solution. In a glass flask, 203 mL of the sample was titrated with 0.025 Eq/L $Na_2S_2O_3$ to a pale straw colour; then 2 mL freshly prepared starch solution was added and the titration was continued to the first disappearance of the blue colour. As 1.0 mL of 0.025 Eq/L $Na_2S_2O_3$ is equivalent to 0.2 mg of oxygen, so 5 mL of $Na_2S_2O_3$ was equivalent to the mg/L of DO.

Nitrite level (mg/L) was measured by the standard environmental protection agency methods[31]. The samples were filtered through a 0.45-pm-pore-diameter filter membrane to remove the suspended solids. The pH value was adjusted to 5-9 with 1.0 Eq/L HCl and 2 mL of colour reagent was added to 50 mL sample and mixed. Absorbance of samples and standards were measured at 543 nm after 30 min against water blank. A blank was prepared by adding 50 mL of nitrite-free distilled water and 2 mL of colour reagent. A standard curve was prepared by plotting absorbance of standards against NO_2-N concentration. The concentration of samples was calculated using the regression line equation produced from the curve. The determinations of pH, salinity (%), turbidity, DO, and nitrite

contents were repeated three times in water samples.

Ethics statement

The protocol was approved by the Research Ethics Committee of the Faculty of Science, Tanta University (permit no. 0164). All experiments were performed in the Animal Facility of Zoology Department, Faculty of Science, Tanta University.

Statistical analysis

Data were expressed as mean ± standard deviation. Response variables were checked for normality using Shapiro-Wilk test and Bartlett's test for homogeneity of variances. The similarity between culicine species communities in breeding sites was calculated using Bray-Curtis' test. The differences in the physicochemical parameters and species percentage among sites were tested using Kruskal-Wallis test. In the case of significant difference, a post-hoc analysis was performed using Wilcoxon test combined with Bonferroni correction. One-way ANOVA was used to compare the differences of salinity and Nitrite content parameters among sites. Tukey's test was used for pairwise analysis between the tested sites. For multiple comparisons, the *P* values were adjusted according to Bonferroni correction to control the familywise error rate. Multiple regression analysis was carried out to explore the association between culicine species and physicochemical variables. Statistical analysis was performed using Rcmdr package in R software, Version 3.6.1[32].

Results

Culicine species communities in the breeding sites

A total of 1500 larvae were sampled from Al-Beshlawy drainage canal, El-Khartoum irrigation ditch, and Tanta man-made ground hole. Five culicine species were identified in Al-Beshlawy drainage canal (Table 1). They were *Culex pipiens* Linnaeus (95.0%), *Cx. univittatus* Theobald (2.6%), *Cx. antennatus* (Becker) (1.2%), *Cx. quinqueifasciatus* Say (0.8%), and *Cx. perexiguus* Theobald (0.4%). Three species were identified in Beheira breeding site: *Cx. pipiens* (97.6%), *Cx. antennatus* (1.6%), and *Cx. univittatus* (0.8%). Five species were identified in Tanta man-made ground hole. They were *Cx. pipiens* (85.6%), *Cs. longiareolata* Macquart (6.0%), *Cx. univittatus* (4.6%), *Cx. antennatus* (3.2%), and *Cx. quinqueifasciatus* (0.6%).

Table 1: Percentages (mean ± standard deviation) of identified culicine larvae in Al-Beshlawy drainage canal (Giza), El-Khartoum irrigation ditch (Beheira), and Tanta man-made ground hole (Gharbia).

	Al-Beshlawy Drainage canal	El-Khartoum irrigation ditch	Tanta man-made ground hole	*P*-value
Culex pipiens	95.0 ± 2.9[a]	97.6 ± 2.8[a]	85.6 ± 4.2[b]	<0.001
Culex univittatus	2.6 ± 1.8 [a]	0.8 ± 1.3 [a]	4.6 ± 4.0 [a]	0.124
Culex antennatus	1.2 ± 0.8 [a]	1.6 ± 1.5[a]	3.2 ± 2.5 [a]	0.332
Culex quinquefasciatus	0.8 ± 0.4 [a]	0.0[a]	0.6 ± 0.9 [a]	0.070
Culex perexiguus	0.4 ± 0.9 [a]	0.0 [a]	0.0 [a]	0.368
Culiseta longiareolata	0.0[b]	0.0[b]	6.0 ± 4.1[a]	0.001

[a,b]: values with same small letter in same row show no significant difference at $P \geq 0.025$ (Wilcoxon test combined with Bonferroni correction). Species dominance: eudominant > 30%, dominant 10-30%, subdominant 5-10%, minor 1-5%, and rare < 1% according to Engelmann[33].

In the three breeding sites, *Cx. pipiens* was considered eudominant, while *Cx. antennatus* appeared to be minor. In Al-Beshlawy drainage canal, *Cx. antennatus* and *Cx. univittatus* were minor, while *Cx. quinqueifasciatus* and *Cx. perexiguus* were rare. In El-Khartoum irrigation ditch, among the identified three species only *Cx. univittatus* was rare. In Tanta man-made ground hole, *Cs. longiareolata* was subdominant, both *Cx. antennatus* and *Cx. univittatus* were minor, and *Cx. quinqueifasciatus* was rare, as shown in Table "1".

Bray-Curtis' dissimilarity showed that all breeding sites tested were similar to each other (Table 2). However, the highest dissimilarity was recorded between El-Khartoum irrigation ditch and Tanta man-made ground hole with an index of 0.12; while the lowest dissimilarity was observed between El-Khartoum irrigation ditch and Al-Beshlawy drainage canal hole with an index of 0.03.

Table 2: Bray-Curtis dissimilarity matrix among breeding sites: Al-Beshlawy drainage canal (Giza), El-Khartoum irrigation ditch (Beheira), and Tanta man-made ground hole (Gharbia).

	Al-Beshlawy drainage canal	El-Khartoum Irrigation ditch	Tanta man-made ground hole
Al-Beshlawy drainage canal		0.03	0.10
El-Khartoum irrigation ditch	0.03		0.12
Tanta man-made ground hole	0.10	0.12	

Ecological parameters (diversity indices) in the sites

Several diversity indices including species diversity, equitability, and concentration of dominance were calculated in the breeding sites (Table 3). Tanta man-made ground hole had the highest value of culicine mosquito diversity and equitability, while El-Khartoum irrigation ditch had the lowest values. The highest dominance concentration value was reported in El-Khartoum irrigation ditch, while the lowest value was in Tanta man-made ground hole.

Table 3: Number of culicine species, diversity, equitability, and concentration of dominance in the breeding sites: Al-Beshlawy drainage canal (Giza), El-Khartoum irrigation ditch (Beheira), and Tanta man-made ground hole (Gharbia).

	Al-Beshlawy drainage canal	El-Khartoum Irrigation ditch	Tanta man-made ground hole
Number of species	5	3	5
Species diversity	0.26	0.13	0.58
Equitability	0.14	0.07	0.33
Concentration of dominance	0.90	0.95	0.74

The physicochemical parameters of the breeding sites

Physicochemical characteristics of mosquito breeding sites are important to determine the suitability of the environment for mosquitoes.

One-way ANOVA results showed significant differences among the breeding sites in salinity (%) and dissolved nitrite content ($F_{2,6} = 50.25$, $p < 0.001$ and $F_{2,6} = 5.87$, $p = 0.039$, respectively). Tukey's

test showed that salinity (%) in sites exhibited significant differences in pairwise comparison (Table 4). Regarding dissolved nitrite content, El-Khartoum irrigation ditch exhibited higher ($P < 0.05$) nitrite content than in rural Giza breeding site. Otherwise, pH, turbidity, and DO content showed no significant differences among the three breeding sites.

Table 4: Physicochemical parameters (mean ± standard deviation) of breeding sites: Al-Beshlawy drainage canal (Giza), El-Khartoum irrigation ditch (Beheira), and Tanta man-made ground hole (Gharbia).

	Al-Beshlawy drainage canal	El-Khartoum Irrigation ditch	Tanta man-made ground hole
Temperature	32.00 ± 7.42 [a]	28.63 ± 5.83 [a]	20.75 ± 4.24 [a]
pH	8.11 ± 0.42 [a]	7.85 ± 0.71 [a]	7.79 ± 0.13 [a]
Salinity (%)***	3.37 ± 0.45 [a]	1.33 ± 0.25 [b]	5.10 ± 0.61 [c]
Turbidity (NTU)	11.10 ± 11.57 [a]	5.69 ± 3.84 [a]	3.86 ± 4.39 [a]
DO (mg/L)	0.33 ± 0.58 [a]	0.30 ± 0.44 [a]	0.73 ± 0.12 [a]
Nitrite (mg/L)*	0.20 ± 0.09 [a]	0.98 ± 0.40 [b]	0.40 ± 0.35 [ab]

NTU: nephelometric turbidity unit, DO: dissolved oxygen content. *,***: refer significant differences among means in sites at $P < 0.05$ and $P < 0.001$, respectively. [a-c]: values with the same small letter in same row are not significantly different at $P \geq 0.025$ (One-way ANOVA with Tukey's post-hoc test and Bonferroni correction).

Association between culicine species relative abundance and physicochemical characteristics

The stepwise multiple regression analysis indicated an association between most physicochemical parameters in the breeding sites and the relative abundance of the culicine species. Of the five variables examined, four variables (salinity, pH, turbidity, and nitrite) were important predictors for the identified culicine species. The results indicated that salinity was the most important predictor for four culicine species abundance.

Cx. pipiens abundance appeared negatively associated with salinity ($R^2 = 0.787$, $P = 0.001$); predicted abundance = −0.01931 (salinity) + 2.02815. However, both *Cx. univittatus* and *Cx. antennatus* abundances were positively associated with salinity ($R^2 = 0.55$, $P = 0.023$; $R^2 = 0.55$, $P = 0.022$). *Cx. univittatus* predicted abundance = 0.18022 (salinity) − 0.23456, whereas predicted abundance of *Cx. antennatus* = 0.13359 (salinity) − 0.01855. Concerning *Cx. quinqueifasciatus*, it was inversely related to nitrite ($R^2 = 0.78$, $P = 0.002$); predicted abundance = −0.42826 (nitrite) + 0.00534. *Cx. Perexiguus* was positively associated with both turbidity and pH ($R^2 = 0.72$, $P = 0.025$ and $P = 0.044$, respectively); predicted abundance = 0.19764 (pH) + 0.24017 (turbidity) − 1.66854. Regarding *Cs. longiareolata*, it had a positive association with both salinity and nitrite ($R^2 = 0.83$, $P = 0.002$ and $P = 0.017$, respectively); predicted abundance = 0.28708 (salinity) + 0.75985 (Nitrite) − 0.35780.

DISCUSSION

Six culicine species were identified in the current study in the tested breeding habitats (Giza, Beheira, and Gharbia Governorates). These were *Cx. pipiens*, *Cx. univittatus*, *Cx. antennatus*, *Cx. quinqueifasciatus*, *Cx.*

perexiguus, and *Cs. longiareolata*. In Giza, Al-Beshlawy drainage canal community consisted of the first five species of *Culex*, whereas El-Khartoum irrigation ditch community consists of only *Cx. pipiens*, *Cx. Univittatu*s, and *Cx. Antennatus*, and Tanta man-made ground hole community consisted of *Cx. pipiens*, *Cx. univittatus*, *Cx. antennatus*, *Cx. quinqueifasciatus*, and *Cs. longiareolata*. Similarly, Mostafa *et al.*[34], Abdel-Hamid *et al.*[12], and Abdel-Hamid *et al.*[13] identified the same species in different Governorates in Egypt. The observed differences in species communities between the tested breeding sites were checked using Bray-Curtis dissimilarity test. Bray-Curtis matrix showed low dissimilarity among the breeding sites in the culicine species. The lowest dissimilarity was recorded between El-Khartoum irrigation ditch and Al-Beshlawy drainage canal, while the highest dissimilarity was recorded between El-Khartoum irrigation ditch and Tanta man-made ground hole. This dissimilarity could be attributed to the observed differences in the abundance of *Cx. pipiens*, *Cx. quinqueifasciatus*, *Cx. perexiguus*, and *Cs. longiareolata* in these sites. According to the number of species identified and their percentages, El-Khartoum irrigation ditch had the least diversity with only three recorded species, while Tanta man-made ground hole had the highest diversity, and Al-Beshlawy drainage canal was intermediate in diversity, equitability, and dominance. The intermediate levels in this site could be explained by the action of competition that regulates diversity. The three sites had low equitability values that defined as the extent of the representation by equal numbers of individuals of different species of a given community. This is obviously because of the high percentages of *Cx. pipiens* in all tested breeding sites, which in turn led to the high concentration of dominance in the three breeding sites. The concentration of dominance was mostly clear in El-Khartoum irrigation ditch site, as a consequence of a low number of species occupied this breeding site. To explain the

suitability of the sites to the inhabiting species, the physicochemical characteristics of these sites were also determined.

In the present study, the temperature range recorded in the three breeding sites was 21-32.00°C. So, culicine mosquitoes seem to adapt to this wide range of temperatures. These results agreed with Kenawy *et al.*[23] who observed a temperature range of 17-30°C for *Cx. pipiens*, *Cx. perexiguus*, *Ochlerotatus caspius*, *Cx. pusillus*, and *Cs. longiareolata* in Cairo Governorate, Egypt. The results indicate that the pH of the sampled breeding sites in rural and urban areas was slightly alkaline and ranged between 7.79 and 8.11. These results agreed with Pelizza *et al.*[35] and Oyewole *et al.*[36] who found that mosquito larvae preferred neutral or slightly alkaline water. Water salinity exhibited significant differences among mosquito breeding habitats in Beheira, Giza, and Gharbia with values of 1.33, 3.36, and 5.1, respectively. The high salinity in Gharbia urban breeding site might be attributed to anthropogenic activities and salts inflows in drainage water[37]. Culicine mosquitoes are reported to prefer fresh-water for oviposition[38]. In the present study, the presence of five species in the high salinity water may reflect adaptation to the breeding site. The water turbidity values of breeding sites ranged from 3.86 to 11.1 NTU. In other words, mosquitoes colonized aquatic habitats with wide ranges of turbidity. The low turbidity in Gharbia urban site maybe because it is a man-made hole with restricted drainage. Culicine larvae preferred turbid water[39]. Kenawy *et al.*[23] found that *Cx. pipiens*, *Cx. perexiguus*, and *Cx. pusillus* tolerated highly turbidity. Unexpectedly, DO levels were low in the three breeding sites with a range of 0.3-0.73 mg/L. Similar results were reported in Kenya[40] and Russia[41]. Low DO levels in the three sites may be due to anthropogenic activities like sewage discharge, leaching from farmland and agriculture, as well as microbial activities and decomposition of organic matters. This explanation was suggested by Popoola and

Otalekor[42]. Silberbush *et al*.[43] suggested that when DO levels decreased in water, larvae seek access to atmospheric oxygen for development. The dissolved nitrite concentrations were 0.19, 0.39, and 0.98 mg/L in Al-Beshlawy drainage canal, Tanta man-made ground hole, and El-Khartoum irrigation ditch sites, respectively. The high nitrite concentration in El-Khartoum irrigation ditch may be explained by excesses of nitrogenous agricultural wastes, fertilizers, and human and domestic animal faeces drained into water[44]. Kenawy *et al*.[23] found *Cx. pipiens*, and *Cs. longiareolata* breeding in water with nitrite levels of 0.04 - 0.23 mg/L in Cairo Governorate. To link between species relative abundance in the sites and the physicochemical characteristics, a stepwise multiple regressions analysis was also performed in the current study.

It is known that the relative abundance of some culicine mosquitoes is correlated with environmental variables. So, the categories described by Engelmann[33] based on the numerical dominance of a species could be explained. In all breeding sites, *Cx. pipiens* was considered eudominant species similar to the previous reports[12,23,34]. The highest abundance was recorded in El-Khartoum irrigation ditch, despite that the highest nitrite content was detected. These results are consistent with the information reported in Kuwait by Salit *et al*.[18] that *Cx. pipiens* can tolerate different degrees of nitrite content. *Cs. longiareolata* was subdominant species and identified only in Tanta man-made ground hole. *Cs. longiareolata* larvae showed a positive association with salinity as appeared in the multiple regression analysis. Similarly, Salit *et al*.[18] in Kuwait and Messai *et al*.[19] in Algeria found that *Cs. longiareolata* tolerated high salinity levels. *Cx. univittatus* was minor in Tanta man-made ground hole and Al-Beshlawy drainage canal, but rare in El-Khartoum irrigation ditch, as it had a positive correlation with salinity. *Cx. antennatus* was a minor, and *Cx. quinqueifasciatus* was rare due to high alkalinity. Abdel-Hamid *et al*.[12]

also found that larval densities decreased as pH increased. The only appearance of *Cx. perexiguus* in Al-Beshlawy drainage canal was attributed to pH and turbidity as reported in the multiple regression analysis. Adebote *et al*.[45] and Dejenie *et al*.[46] reported that culicine larvae were positively associated with the pH.

In conclusion, the results indicated that salinity is the best indicator for abundance of *Cx. pipiens*, *Cx. univittatus*, *Cx. antennatus*, and *Cs. longiariolata*. Nitrite predicts larval densities of *Cx. quinqueifasciatus* and *Cs. longiariolata*; whereas, turbidity and pH are common indicators for *Cx. perexiguus* abundance.

AUTHORS' CONTRIBUTIONS
MAS, AIS, and WSM conceived and designed research. NAE and WSM conducted experiments. WSM analysed data. All authors wrote and approved the manuscript.

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مجتمعات البعوض (DIPTERA: CULICIDAE) وعلاقتها بالخصائص الفيزيائية والكيميائية في ثلاثة مواقع لتكاثره بمصر

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يتنوع البعوض ويتوزع عالميا، وتعتبر مجارى المياه العذبة مواقع تكاثر لأنواعه المختلفة. وقد تؤثر الخصائص الفيزيائية والكيميائية لمواقع تكاثر البعوض على تركيب مجتمع البعوض ووفرته. لذلك هدفت هذه الدراسة إلى تحديد أنواع البعوض ووفرتها تبعا للخصائص الفيزيائية والكيميائية لموقعين تكاثر ريفيين "مصرف البشلاوى بالجيزة وقناة صرف الرى بقرية الخرطوم بالبحيرة" وموقع حضرى "حفرة من صنع الإنسان بطنطا بالغربية" بمصر. وكانت العوامل الفيزيائية والكيميائية محل الدراسة هي درجة الحرارة، والأس الهيدروجينى للمياه، ومقدار كل من الملوحة والعكارة، وتركيز كل من الأكسجين والنتريت في المياه. تم حساب مؤشرات التنوع (عدد الأنواع بالموقع والتنوع وتكافؤ التوزيع وتركيز السيادة) للبعوض. أظهرت النتائج تعريف ستة أنواع من البعوض في مواقع التكاثر الثلاثة محل الاختبار هي "Culex pipiens و Cx. univittatus و Cx. antennatus و Cx. quinqueifasciatus و Cx. perexiguus و Culiseta longiareolata". وكانت جميع الأنواع المُعرَّفة من الأنواع المحلية المصرية. وقد اتضح سيادة البعوض من النوع Cx. pipiens في جميع مواقع التكاثر الحضرية والريفية محل الدراسة. وتراوحت قيم مؤشر "براى – كورتيس" للاختلاف بين المواقع المختبرة من 0.03 إلى 0.12. ويمكن أن يعزى هذا الاختلاف إلى غياب بعض أنواع البعوض في بعض المواقع ، بالإضافة إلى الاختلاف ذو الدلالة فى النسبة المئويه لكل من Cx. pipiens و Cs. longiareolata بين المواقع المختلفة. كما وجد اختلاف ذو دلالة في ملوحة الماء ومحتوى النتريت المذاب بين مواقع التكاثر المختلفة. وأظهر تحليل الانحدار المتعدد بين أنواع البعوض المعروفة في المواقع المختلفة والعوامل الفيزيائية والكيميائية أن مقدار كل من الملوحة ومحتوى النيتريت والعكاره والأس الهيدروجينى للمياه تعتبر عوامل رئيسية عند التنبؤ بوجود أنوع معينة من البعوض في المجارى المائية.