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Species Composition and Relative Abundance of Mosquito Larvae in Suez Canal Zone, Egypt

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Authors' contributions

This work was carried out in collaboration between all authors. Author MS designed the study and wrote the first draft of the manuscript. Author AEH performed literature review, statistical analysis and arranged the structure of the whole paper. Authors ME, WA and AEZ revised the whole paper. All authors read and approved the final manuscript.

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ABSTRACT

Mosquito-borne diseases have a great impact on human and animal health throughout the world, including Egypt. A survey was conducted at Suez Canal Zone for 8 months, prolonged from November 2014 till April 2016 to identify the mosquito larvae and to investigate the different breeding habitats preferences of mosquito's larvae. Larvae were collected using a standard dipping with a small ladle. A total of 14806 mosquito larvae were collected from 7 different breeding habitats and found belonging to 5 genera and 10 species; *Culex pipiens* L. *Culex perexiguus* Theobald, *Culex* (*Barraudius*) *pusillus* Macquart, *Anopheles (Cellia) multicolor* Cambouliu, *Anopheles* (*Anopheles*) *tenebrosus* Dönitiz, *Anopheles* (*Cellia*) *pharonsis* Theobald, *Culiseta longiareolata* (Macquart), *Ochlerotatus detritus* Haliday, *Ochlerotatus caspius* (Pallas) and *Uranotaenia unguiculata* Edwards. Out of these, 5 species are considered as high potential vector of diseases in Egypt. Results indicated that *Cx. pipiens* is the most common vector prevalent in all months representing 66.90% (n=9905 larvae) of total collection, followed by *Cx. perexiguus* 10.06%

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(n=1490 larvae). Different habitats of Suez Canal area are environmentally suitable for mosquito breeding and therefore the probability of emergence/re-emergence of the mosquito-transmitted diseases becomes enhanced. So, the present study provides the baseline information for decision makers to take necessary optimal control strategies to mitigate mosquito nuisance, proliferation rate and the areas under risk of potential diseases transmission.

Keywords: Mosquitoes survey; species composition; diversity; abundance; Suez Canal area.

1. INTRODUCTION

Remarkably, among all insects, mosquitoes have a greater importance in terms of major public health problems, and transmit several diseases like Dengue Fever, Malaria and Filariasis. This is attributed to their abundance, diversity, their efficient capacity and potentiality as vectors of multiple diseases and the recurrent infection [1,2]. Per the World Health Organization (WHO) reports, globally, almost around one million people died and 247 million people were ill in tropical and subtropical region in 2006 [3] and there is no part of the world that is immune to this risk [4]. Mosquitoes genera differ in their habitat requirements and life cycle timeframe, as well as its surveillance are a prerequisite to an effective efficient environmentally sound mosquito control program [5].

Mosquitoes prefer to breed in all sorts of stagnant water. Running streams and creeks with any water movements or ponds with predators such as fish, frogs and Dragonflies are not good breading sites for mosquitoes [6].

Larval development, the emergence of adult and other developmental processes in the larval habitats of mosquitoes, play main role in the determination of abundance and distribution of mosquitoes [7].

Survey of mosquitoes in Egypt was conducted on different intervals by many authors [8–14] indicating the existence of twenty-nine mosquito species; Eighteen culicine and eleven anopheline species. Out of which twelve mosquito species were previously reported at Ismailia Governorate, Canal Zone, while Abdel-Hamid et al. [15] reported only eight species in the same Governorate.

The favorable environmental unique features characterizing the Suez Canal area assist in flourishing of different mosquitos' species and their temporal/spatial wide spread in and around the area. Urban extension, dissimilar urban areas, an existence of rural and desert areas consequently led to the diversity of mosquito habitats [16]. The recent increase in ecological and environmental modification due to agricultural activities and urbanization has been observed to contribute to spreading the breeding of various species of mosquito [17]. So, this underscores the need for the current documentation of the mosquito fauna and their habitats.

Therefore, mosquito larval habitat ecology is important in determining larval densities, relative importance of breeding habitats, and species composition as well as the design of mosquito control programs [18].

The present study aimed to study and identify mosquito larval species composition, relative abundance and breeding habitats throughout Suez Canal Zone during the period November 2014 to April 2016. This study explores new breeding habitats in Suez Canal area and provides the baseline information for decision makers to initiate necessary optimal control strategies to mitigate mosquito nuisance, proliferation and the areas under risk of potential diseases transmission.

2. MATERIALS AND METHODS

2.1 Study Area

The study area, representing in the western bank of the Suez Canal (which located in the northeast of Egypt and extends from Port Said, in the North, to Port Taufiq, near Suez, in the South) as shown in Fig.1. includes parts of three governorates; Port Said, Ismailia and Suez. It occupies an area of 7523.008 km^2 and lies between latitude 29° 30' N to 31° 30' N and longitude 32° 10' E to 32° 40' E. It is bordered on the north by the Mediterranean Sea, west and south by eastern desert, and from the northern east by a part Sinai Peninsula.

2.2 Mosquito Larval Surveys

Field trips were conducted of all accessible breeding habitats for 8 months in-between two consecutive years, 2014-2015, 2015-2016. Around 300 different locations were visited, 155 were considered positive for the presence of mosquito larvae as illustrated in Fig. 1. Mosquito's larvae were collected by a Standard dipping using a small ladle (10.5 cm in diameter with a 90-cm wooden handle), from stagnant aquatic habitats. Different numbers of dips were taken based on the size of the breeding site, water level and the availability of larvae. From each breeding site, 2-10 dips were taken.

Collected larvae were placed in labeled glass vials containing a fixative solution (70% Ethyl Alcohol), the larvae were permanently prepared on slides and taxonomically identification using the Keys of Harbach [19] and Glick [20]. Procedures and precautions, regarding larval collection and transportation, were carried out according to WHO [21] guidelines.

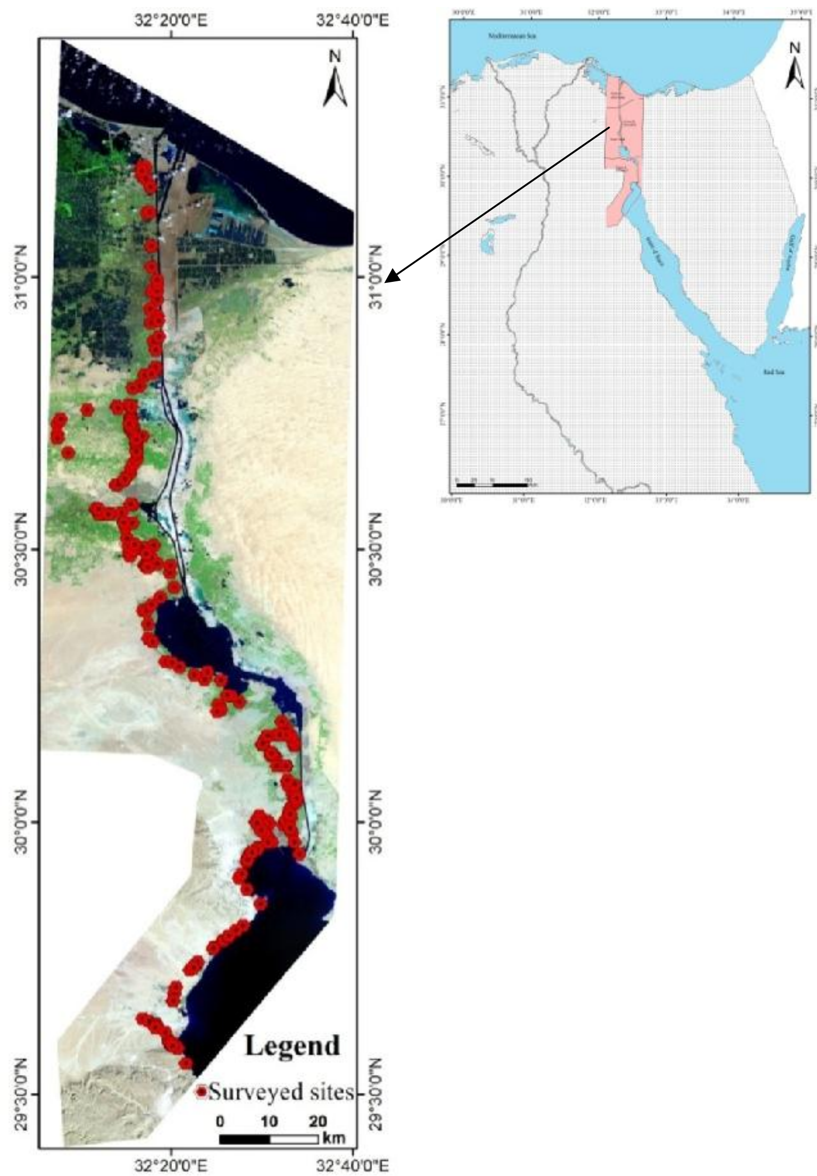

Fig. 1. Localization of the study area; Surveyed sites

Natural and physical characteristics of each habitat site were described and recorded as an intensity of light, presence and types of vegetation, a condition of the water. Each visited site was geo-referenced using a hand-held Global Positioning System device (GPS, Magellan 320-USA).

2.3 Data Analysis

The mosquito larval density in each breeding habitat was calculated using the following formula [22]:

$$D = l / L \cdot 100\%$$

Where D is density, l is number of specimens of each mosquito species, and L is number of all specimens.

Means and Standard Errors were calculated for larval densities of the collected mosquito species at each habitat. The statistical data analysis was done using SPSS software (version 19 for windows). Variations in larval counts (mean densities) among habitat types were analyzed using mean comparison and one-way analysis of variance (ANOVA).

3. RESULTS

From survey area a total number of 14806 mosquitoes larvae belonging to 5 genera and 10 species were recorded; 3 *Culex*, 3 *Anopheles*, 2 *Ochlerotatus* and one of each *Culiseta* and *Uranotaenia* namely; *Culex pipiens* L., *Culex perexiguus* Theobald, *Culex* (*Barraudius*) *pusillus* Macquart, *Anopheles (Cellia) multicolor* Cambouliu, *Anopheles* (*Anopheles*) *tenebrosus* Dönitiz, *Anopheles* (*Cellia*) *pharonsis* Theobald, *Culiseta longiareolata* (Macquart),*Ochlerotatus detritus* Haliday, *Ochlerotatus caspius* (Pallas) and *Uranotaenia unguiculata* Edwards.

As illustrated in (Table 1, Fig. 2), our tabulated results indicated that; *Cx. pipiens* was the most dominant species in the whole study area, representing 66.90% (n=9905 larvae) of the total collection.

Table 1. Shows that the relative abundance of mosquito larval species was different in all breeding habitats in the study area

Species	Total	%
Culex pipiens	9905	66.90
Culex perexiguus	1490	10.06
Culex pusillus	1023	6.91
Anopheles multicolor	56	0.38
Anopheles tenebrosus	104	0.70
Anopheles pharonsis	3	0.02
Culiseta longiareolata	166	1.12
Ochlerotatus detritus	1925	13.00
Ochlerotatus caspius	87	0.59
Uranotaenia unguiculata	47	0.32
Total: 10 species	**14806**	**100.00**

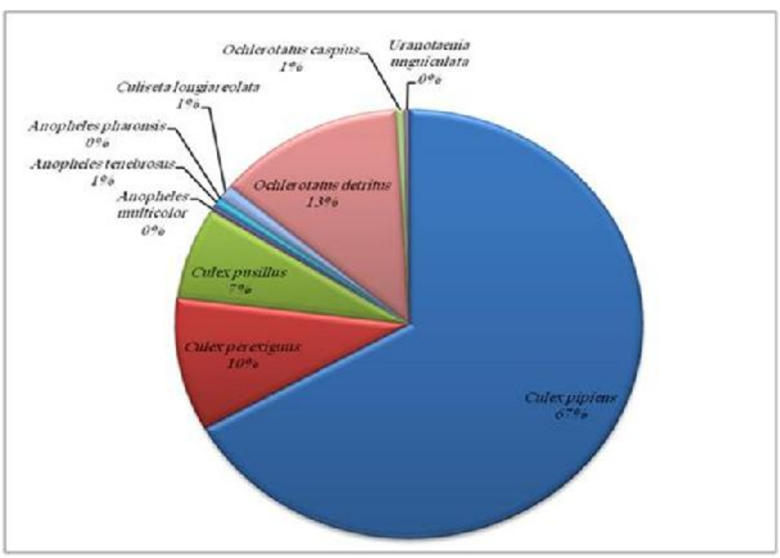

Fig. 2. Relative abundance of mosquito larval species was different in all breeding habitats in the study area

The second most common species was *Oc. detritus* representing 13.00% (n=1925 larvae). The third abundant species was *Cx. perexiguus* representing 10.06 % (n=1490 larvae) of the total collection. *Cx. pusillus* species encountered 6.91% (n=1023 larvae), while *Cs. longiareolata* represented 1.12% (166 larvae). On the other hand, *An. tenebrosus* and *Oc. caspius* reported 0.70% (n=104 larvae) and 0.59% (n=87 larvae).The species *An. multicolor* and *Ur. unguiculata* comprising relatively same abundance; represented 0.38% (n=56 larvae) and 0.32% (n=47 larvae) respectively. *Ur. unguiculata* was collected only at December 2015 and the least abundant species was *An. pharonsis* recording 0.02% (n=3 larvae).

The breeding habitats inspected, during the whole period of study, were categorized into seven larval habitat types; sewage, seepage, drainage canals, irrigation canals, agriculture drainage canals, unused irrigation water basins, drainage fish farms. The first five types of habitats (Fig. 3) were the most productive sites (31% of the collected larvae, 22%, 17%, 15% and 11% respectively). These encountered habitats have been categorized to observe and investigate types of mosquitoes' habitat in Suez Canal area. There was significant difference in species occurrence in four breeding habitats; drainage canals, sewage, agriculture drainage canals and seepage (*P*=0.05).

As indicated in (Table 2), larvae of *Cx. pipiens, Cx. perexiguus, Cx. pusillus, An. multicolor, An. tenebrosus, Cs. longiareolata, Oc. detritus* and *Oc. caspius* co-existed in five type of breeding habitat (drainage canal, sewage, agriculture drainage canals, seepage and irrigation canal), except *Cs. longiareolata* was not recorded in seepage and irrigation canal, and *Oc.caspius* was not found in agriculture drainage canals.

Cx. pipiens and *Cx. perexiguus* were breed along with *Cs. longiareolata* in unused irrigation water basin and drainage fish farm, while *Oc. detritus* and *Oc. caspius* co-existed in drainage fish farm. The only recorded larvae of *An. pharoensis* in seepage with low abundance (0.3%) and *Ur. unguiculata* in sewage water (1.2%) (mainly cesspit).

A significant difference was observed in *Culex pipiens* larvae presence in the different habitats. The most preferred habitat of that larvae was unused irrigation water basin (88.9 %) followed by drainage canals (80.5 %).

Cx. perexiguus was higher in seepage (25.1%) followed by agriculture drainage canals (12.01%) than the other habitats. The large occurrence of *Cx. pusillus,* (27.71%) found in sewage (15.9%) followed by seepage (12.2%). *Cs. longiareolata* was the recorded in high levels in agriculture drainage canals (5.0%) followed by unused irrigation water basin (3.5%).

The relative abundance of *Oc. detritus* and *Oc. caspius* were higher in drainage canals of fish farm (87.5%, 11.7% respectively), followed by irrigation canals in case of *Oc. detritus* (17.8%) and see page in case of *Oc. caspius* (1.9%). On the other hand, the larvae of *An. multicolor* and *An. tenebrosus* occurring in different type of breeding habitat, *An. multicolor* recorded higher larval density in irrigation canals (0.9%) while *An. tenebrosus* in agriculture drainage canals (5.5%).

The climate of Egypt has only two seasons: A mild winter from November to April and a hot summer from May to October (Climate of Egypt). As illustrated in (Table 3, Fig. 4), regarding to mosquito vectors in Egypt, seasonal variation and species composition of mosquito larvae collected during the study period showed that; *Cx. pipiens* and *Cx. perexiguus* prevails in two seasons but with different densities, recorded the highest density existence in April 2016 (mild winter) encountered (604.9 and 192.3 respectively) followed by November 2014 (227.4) in case of *Cx. pipiens* and January 2015 (10.4) in case of *Cx. perexiguus*. In a hot summer months; May 2015 and October 2015 recorded (265.8 and 13.5 respectively). *Cx. pipiens* has a significant difference in April 2016, while *Cx. perexiguus* have significant differences in different months.

During the studied period (November 2014 - April 2016), *Oc. caspius* recorded high abundance in April 2016 (9.7), followed by February 2016 (3.8), while a low existence was observed in hot summer; January 2015 (1.3). *An. multicolor* was detected in high abundance (6.1) in December 2014. *An. pharonsis* was found in low abundance recording (0.5) in May 2015 and (1.0) in October 2015.

4. DISCUSSION

This study indicates species composition, relative abundance, seasonal variation and habitat specificity of mosquitoes in Suez Canal Zone. Mosquito fauna was represented by 5 genera and 10 species; 3 C*ulex*, 3 *Anopheles*, 2 *Ochlerotatus* and one of each *Culiseta* and *uranotaenia.*

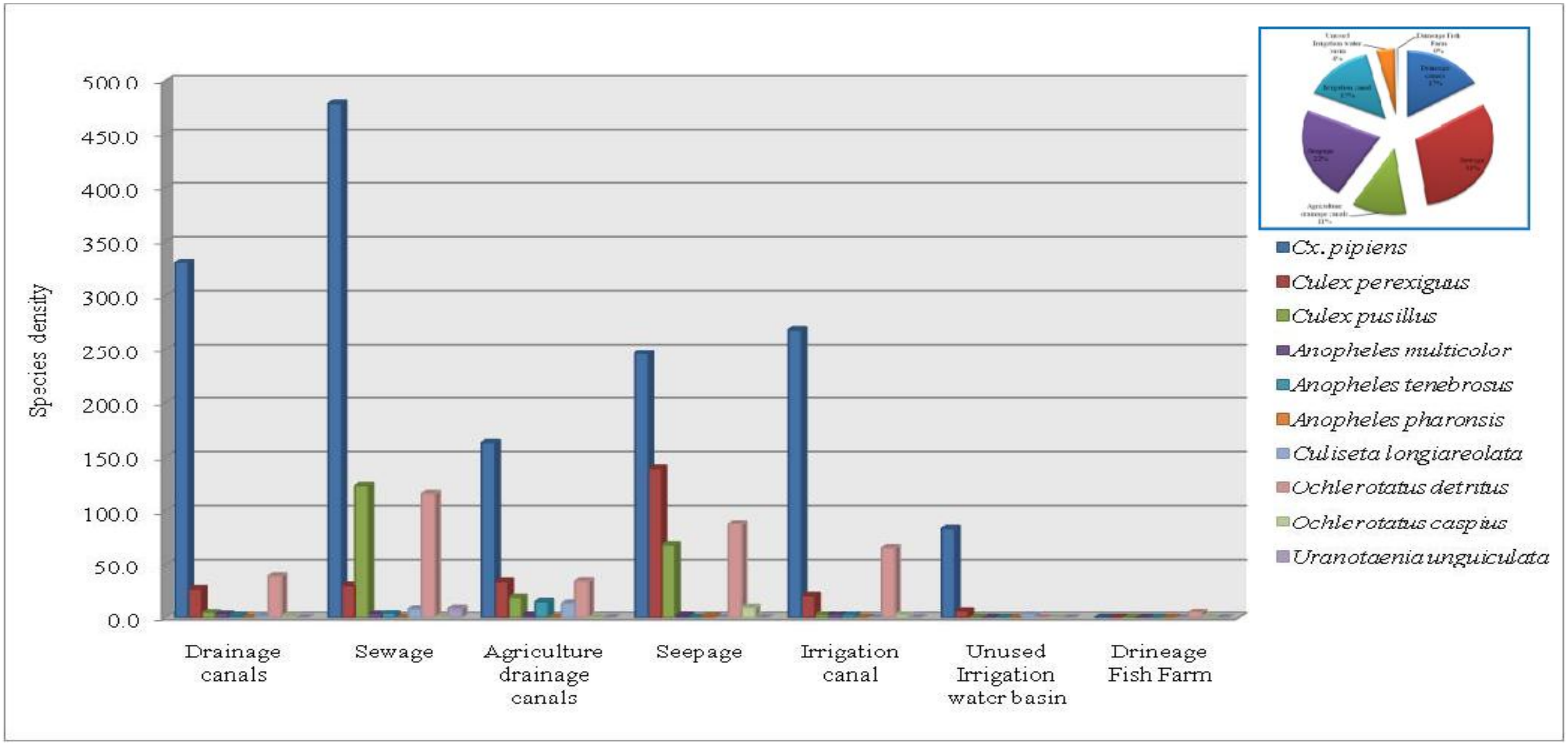

Fig. 3. Relative productivity of collected larvae across different breeding habitat

Table 2. Relative abundance of mosquito larvae collected in different breeding habitats at Suez Canal Zone during the period (November 2014 –April 2016)

Habitat Type	***Species density***										**Sum**
	Cx. pipiens	*Cx. perexiguus*	*Cx. pusillus*	*An. multicolor*	*An. tenebrosus*	*An. pharonsis*	*Cs. longiareolata*	*Oc. detritus*	*Oc. caspius*	*Ur. unguiculata*	
Drainage canals	330.8 (80.5)	27.1 (6.6)	5.1 (1.2)	4 (1)	2 (0.5)	0.0	1.7 (0.4)	38.9 (9.5)	1.3 (0.3)	0.0	410.7
Sewage	478.5 (61.8)	30.3 (3.9)	122.8 (15.9)	4 (0.5)	4.3 (0.6)	0.0	8.9 (1.1)	115.6 (14.9)	0.4 (0.1)	9.4 (1.2)	774.2
Agriculture drainage canals	162.9 (57.6)	34 (12.01)	19.4 (6.9)	2.4 (0.8)	15.6 (5.5)	0.0	14.1 (5.0)	34.3 (12.1)	0.0	0.0	282.6
Seepage	246.1 (44.3)	139.6 (25.1)	68 (12.2)	2 (0.4)	0.1 (0.02)	1.5 (0.3)	0.0	87.9 (15.8)	10.3 (1.9)	0.0	555.5
Irrigation canals	268.1 (73.2)	21.1 (5.7)	2.9 (0.8)	3.3 (0.9)	2.9 (0.8)	0.0	0.0	65.3 (17.8)	2.7 (0.7)	0.0	366.1
Unused Irrigation water basin	82.9 (88.9)	7 (7.5)	0.0	0.0	0.0	0.0	3.3 (3.5)	0.0	0.0	0.0	93.2
Drainage Fish Farm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6 (87.5)	0.8 (11.7)	0.0	6.4

**Values in parenthesis indicate the relative abundance of total larvae collected at each type of breeding habitat*

Table 3. Temporal variation, species composition and relative abundance of mosquito larvae in Suez Canal Zone

Month	*Cx. pipiens*	*Cx. perexiguus*	*Cx. pusillus*	*An. multicolor*	*An. tenebrosus*	*An. pharonsis*	*Cs. longiareolata*	*Oc. detritus*	*Oc. caspius*	*Ur. unguiculata*
Nov. 2014	227.4	9.6	12.31	1.65	1.20	0.0	1.25	22.5	0.4	0.00
Dec. 2014	19.0	6.6	1.40	6.1	0.00	0.0	0.0	10.5	0.2	9.40
Jan. 2015	81.9	10.4	3.20	2.2	0.00	0.0	8.6	94.2	1.3	0.00
Apr. 2015	183.6	8.9	7.18	5.7	11.50	0.0	6.5	44.4	0.0	0.00
May 2015	265.8	12.2	31.60	0.0	6.90	0.5	0.0	28.1	0.0	0.00
Oct. 2015	68.0	13.5	15.20	0.0	0.00	1.0	0.0	15.4	0.0	0.00
Feb. 2016	118.7	5.6	2.88	0.0	1.70	0.0	0.0	42.7	3.8	0.00
Apr. 2016	604.9	192.3	144.40	0.0	3.60	0.0	11.6	89.8	9.7	0.00

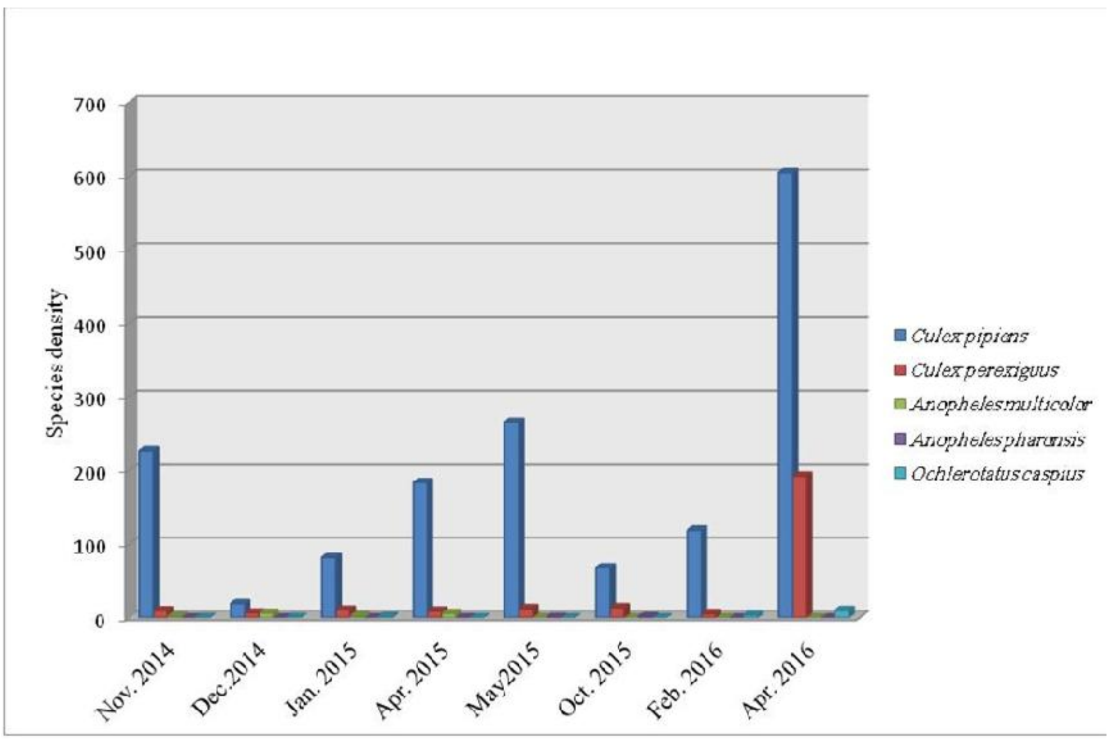

Fig. 4. Temporal variation and relative abundance of mosquitoes' larvae

These species were collected from 155 locations during the study period from November 2014 to April 2016 where replicate visits were conducted to most locations. Commonly, it was noticed that mosquito breeding sites in Suez Canal zone were associated with shallow polluted water pools, water logging/seepage surrounded by different vegetation (sparse or dense, natural or cultivated, merged or submerged) which were partially exposed to sunlight.

The abundance of culicine and anopheline species may be because of their ability to survive in diverse environments as previously as reported by several authors e.g. Dondrop et al. [23] and Simon and Ayani [24].

In April 2016, high larval density was recorded which may be associated with major environmental changes including rises in temperature, modified agricultural practices and others. So, the larval richness mainly depends on structure and quality of the habitats and each species develops in a particular environment such as fresh water, rainwater, sewage, drainage at specific temperature [25].

Regarding mosquito vectors in Egypt, Culicine mosquitoes mainly *Cx. pipens* was the most dominant vector in the whole study area. This species prevails in most locations which is similar to the previous study of El-Said and Kenawy [8,9]. Bahgat et al. [13] and Abdel-Hamid et al. [15]. It was present with high density and collected from stagnant polluted drains associated with human activities; this is compatible with Amr et al. [26], Al-Khalili et al. [27], Knio et al. [28], Ammar et al. [29] and Tran et al. [30]. Also, Oringanje et al. [31] stated that most polluted breeding sites urge the spread of more culicines while these sites don't favor for anopheline proliferation. This indicates the prevalence of the main filariasis vector in various breeding habitats [32] especially in domestic drainage canals and small irrigation canals which are numerous within the study area. *Oc. caspius* has been incriminated to transmit Rift Valley Fever virus during 1977 & 1993 [33,34]. For anopheline species, *An. pharoensis* is the proven malaria vector, while *An. multicolor* incriminated to be malaria vector under experimental conditions [35-40], the two-species preferred brackish pools and seepage habitats, the result agreed with Harbach et al. [10].

Wasim [41] reported that *Cx. pusillus* was collected from brackish pools and ditches like the present findings, also Morsy et al. [12] recorded the species in drainage canals, irrigation water basin and swage which also matches with the presenting observations.

Sewage and domestic drainage canals were located close to residential areas; this indicates that the poor sanitation of the most locations in the study area appears to be responsible for the abundance of mosquito habitats. Also, studies reported a positive relationship between habitat type diversity and mosquito species richness e.g. Kenawy and El-Said [42] Ijumba, et al. [43], Shililu et al. [44].

5. CONCLUSION AND RECOMMENDATIONS

Field surveys and laboratory investigations showed a temporal fluctuation in mosquito larval abundance/existence due to variations in climatic and environmental conditions. Five genera and ten species were recorded in Suez Canal Zone; *Culex pipiens* L., *Culex perexiguus* Theobald, *Culex* (*Barraudius*) *pusillus* (Macquart), *Anopheles (Cellia) multicolor* (Cambouliu), *Anopheles* (*Anopheles*) *tenebrosus* (Dönitiz), *Anopheles* (*Cellia*) *pharonsis* (Theobald), *Culiseta longiareolata* (Macquart), *Ochlerotatus detritus* (Haliday), *Ochlerotatus caspius* (Pallas) and *Uranotaenia unguiculata* (Edwards).

Seasonal variation of mosquito larvae collected during the study period showed that *Cx. pipiens* and *Cx. perexiguus* prevails in the whole period with different densities, recorded the highest density existence in April 2016 encountered (604.9 and 192.3 respectively) followed by Nov. 2014 (227.4) in case of *Cx. pipiens* and Jan. 2015 (10.4) in case of *Cx. perexiguus*.

In order to mitigate and control mosquito proliferation, the present study highly recommends the following;

- Suez Canal Zone is a highly susceptible area for mosquito proliferation and potentiality of diseases transmission, therefore results of this research and similar studies should be considered in environmental assessment and monitoring studies.
- The necessity for the regular monitoring of mosquito breeding habitats/ relative abundance in order to start the effective control programs to eliminate the probability of diseases transmissions.
- Water resources management should be achieved so as to increase an unsuitability of habitats for mosquito breeding, for instance, one of the preferable habitats for *Cx. pipiens* is wastewater discharge areas.
- Individuals' awareness about mosquito-transmitted diseases and how to help in mosquito control programs by the positive actions such as unnecessary standing water (e.g. small ponds, wastewater discharge sites, etc.).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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