



# Spatio-temporal distribution of *Chrysomya megacephala* (Diptera: Calliphoridae), mechanical vector of infectious diseases in the city of Yaoundé (Centre-Cameroon)

Linda S. Guiadem<sup>1</sup> · Christian T. Dhuideu<sup>2</sup> · Hakan Bozdoğan<sup>3</sup> · Arnaud N. Mballa<sup>1</sup> · Sévilor Kekeunou<sup>1</sup>

Received: 13 December 2021 / Accepted: 16 February 2023 / Published online: 8 March 2023  
© African Association of Insect Scientists 2023

## Abstract

The distribution pattern of the fly *Chrysomya megacephala* in the city of Yaoundé in Cameroon is poorly known despite its medical relevance. Following three types of standing (urbanization level) (medium standing, spontaneous standing, and peri-urban standing), we conducted monthly catches of adult flies on three types of waste (organic, inorganic, and animal paddock). The occurrence, distribution pattern, and seasonal abundance associated with abiotic factors (temperature, relative humidity, and precipitation) of *C. megacephala* were studied. In total, 656 fly individuals were sampled across all sites, with the highest abundance observed in mixed organic waste in spontaneous standings. Seasonal fluctuations revealed two peaks of *C. megacephala* abundance, one during the long dry season and the other during the short rainy season. Spearman's correlation test showed that fly's abundance is not significantly linked to temperature, relative humidity and rainfall. The occurrences data revealed that *C. megacephala* in the urban area of Yaoundé, *C. megacephala* was constant, incidental or accidental species. *Chrysomya megacephala* was constant only in mixed organic matter of spontaneous standings. The Fisher, Neyman and Morisita indices show that the mode of distribution of *C. megacephala* was aggregative. Current vector control strategies should also target sarcophagus insects like *C. megacephala* to reduce its abundance and the burden of hydric diseases in Yaoundé neighborhoods.

**Keywords** Distribution · Occurrence · Abiotic factors · Level of urbanization · *Chrysomya megacephala*

## Introduction

*Chrysomya megacephala* is a Diptera widely distributed in tropical and subtropical regions of the world, particularly in Africa and the New World (Yasmeen and Amir, 2022). It plays a leading role in the mechanical transmission of fecal-oral diseases, in particular through its feeding on human

and animal excrement, garbage, and human food (Ngoen-Klan, et al., 2011, Badenhorst and Villet, 2018). In Africa, it exists in almost all sub-Saharan African countries where it causes a public health problem, in particular through its role as a mechanical vector of pathogenic germs (Bohart and Gressitt, 1951, Wells 1991, Irish et al. 2014, Alikhan et al., 2018). The spectrum of germs transmitted mechanically by this insect includes bacteria such as enterohemorrhagic *Escherichia coli* (Migula, 1895) (Castellani and Chalmers, 1919), *Klebsiella pneumoniae* (Trevisan, 1887), *Salmonella typhi* (Schroeter, 1886) (Warren and Scott, 1930), *Staphylococcus aureus* (Rosenbach, 1884), *Pseudomonas aeruginosa* (Schroeter, 1872) (Migula, 1900) and *Aeromonas hydrophila* (Chester, 1901) (Stanier, 1943), that can cause symptoms ranging from watery diarrhea to dysentery or bloody diarrhea in humans (Sukontason, et al., 2007, Chaiwong, et al., 2012, Srivoramas, et al., 2012, Sulaiman et al., 2017). Studies conducted in Argentina by Battan-Horenstein and Gleiser (2018) have suggested that the effective control

✉ Linda S. Guiadem  
simo.linda@yahoo.fr

<sup>1</sup> Plant and Animal Protection Unit, Zoology Laboratory, Faculty of Science, University of Yaoundé I, P.O. Box 812, Yaoundé, Cameroon  
<sup>2</sup> Parasitology and Ecology Laboratory, Faculty of Science, University of Yaoundé I, P.O. Box 812, Yaoundé, Cameroon  
<sup>3</sup> Vocational School of Technical Sciences, Department of Plant and Animal Production, Kırşehir Ahi Evran University, Kırşehir 40100, Turkey

of this species in urban environments can drastically reduce the number of pathological cases linked to infection with fecal-oral diseases especially in very precarious hygiene and sanitation conditions. An optimal control requires a better knowledge of the distribution of this fly species in urban areas as well as the biotic and abiotic parameters that can affect its distribution (Ngoen-Klan et al., 2011). For example, Battan-Horenstein and Gleiser (2018) highlighted the influence of seasonality on the structuring of populations of this species. According to Ngambi (2015), accelerated and poorly controlled urbanization, combined with the growth of human populations in urban areas, complicate the urban waste management in developing countries. The existing equipment for improving the hygiene and sanitation conditions has not kept up with the development of the cities. In some cases, more than half of the urban populations live in neighborhoods not served by the public waste service. Problems are recurrent, especially in spontaneous neighborhoods, with epidemics such as fecal-oral diseases as a result of permanent unsanitary conditions.

In Cameroon, although there are services for the management and treatment of urban waste, the level of transmission of fecal-oral diseases remains alarming. *Chrysomya megacephala* living in urban environments is known to play an important role in this transmission (Feugang, et al., 2012). The distribution of this insect and the factors affecting it remains unknown in our environment. These data are important in the development of effective control strategies against *C. megacephala*. This study aimed to assess (1) the spatial and temporal distribution of occurrence and abundance of *C. megacephala*, (2) the mode of distribution of *C. megacephala*, as well as (3) the effects of some abiotic factors on the population structure of this species in the city of Yaoundé.

## Materials and methods

### Study sites

This study was carried out in the city of Yaoundé (3°52'N 11°31'E) (Fig. 1), Centre Region, Mfoundi Department. Yaoundé, the capital of Cameroon, is subdivided into seven districts and covers an area of 304 km<sup>2</sup>. It has an estimated population of 2,440,462 as of the year 2011, with an average density of 13,558 inhabitants per km<sup>2</sup>. Yaoundé and its surroundings are characterized by the presence of some mountain ranges whose altitude fluctuates between 600 and 1200 m. Yaoundé has a climate with a bimodal rainfall where four seasons are distinguished (Sighomnou, 2004): a long dry season (from mid-November to mid-March), a short rainy season (from mid-March to the end of June), a

short dry season (from July to the end of August) and a long rainy season (from September to mid-November).

The city of Yaoundé is subdivided into standings (level of urbanization) that depend on the living standards of the residents. Thus, we have medium standings with medium or middle incomes, poor or spontaneous standings, and peri-urban standings located at the boundaries of urbanized areas (Ngambi, 2015). For this study, 13 neighborhoods were randomly selected following the districts covered by different types of waste. Thus, we selected four neighborhoods of medium standings (Biyemassi, Nsymeyong, Madagascar, Essos), five spontaneous standings (Nsam, Mokolo, Carrière, Mvog-Ada, Nkoldongo), and four peri-urban standings (Etoug-Ebe, Nkolbisson, Etoudi, Emana).

### Fly sampling and identification

In each selected district, we conducted the catches in three sites: (1) an organic waste bin (containing plant materials, detritus, papers, woods), (2) an inorganic waste bin (containing waste plastics, bottles, irons, clothes, shoes, bags, etc.) and (3) animal paddock (containing animals, and fecal materials).

At each site, catches were realized using a sweep net, once every four weeks for 12 months, from May 2019 to April 2020. Thirty minutes collection time period was achieved at each site from 8-11 am by a well-trained personnel. All collected specimens were stored in labeled pillboxes containing 70% ethanol and transported to the Zoology Laboratory of the University of Yaoundé I for morphological identification and taxonomy classification.

*Chrysomya megacephala* was identified under a binocular magnifying glass using the published identification keys (Kurahashi and Kirk-Spriggs, 2006, Irish et al., 2014, Lutz, et al., 2018).

### Recording of climate parameters

During field investigations, the values of temperature, relative humidity, and daily rainfall from May 2019 to April 2020 were obtained from the Nkolbisson meteorological station of the International Institute for Tropical Agriculture (IITA) (Fig. 2).

### Statistical analysis

The statistical analyses were conducted using Excel, PAST (version 3.12), and R version 4.0.2 (packages “FactoMiner” and “Factoextra”). The PAST software allowed us to run: (1) the chi-square test ( $\chi^2$ ) for frequencies comparison between different standings (level of urbanization) and different seasons; (2) Spearman correlation coefficient (rs) to

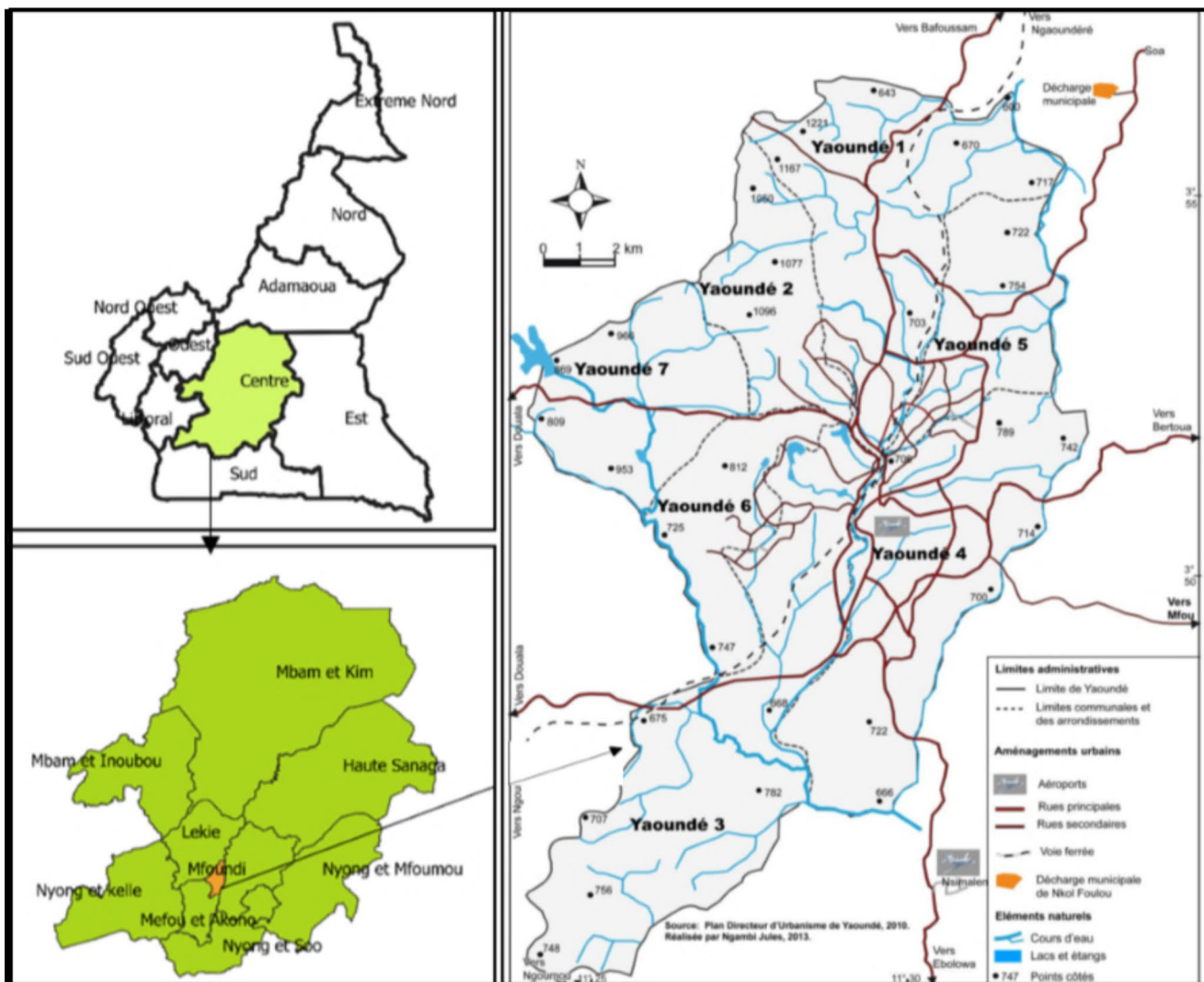


Fig. 1 Map of the districts of the city of Yaoundé

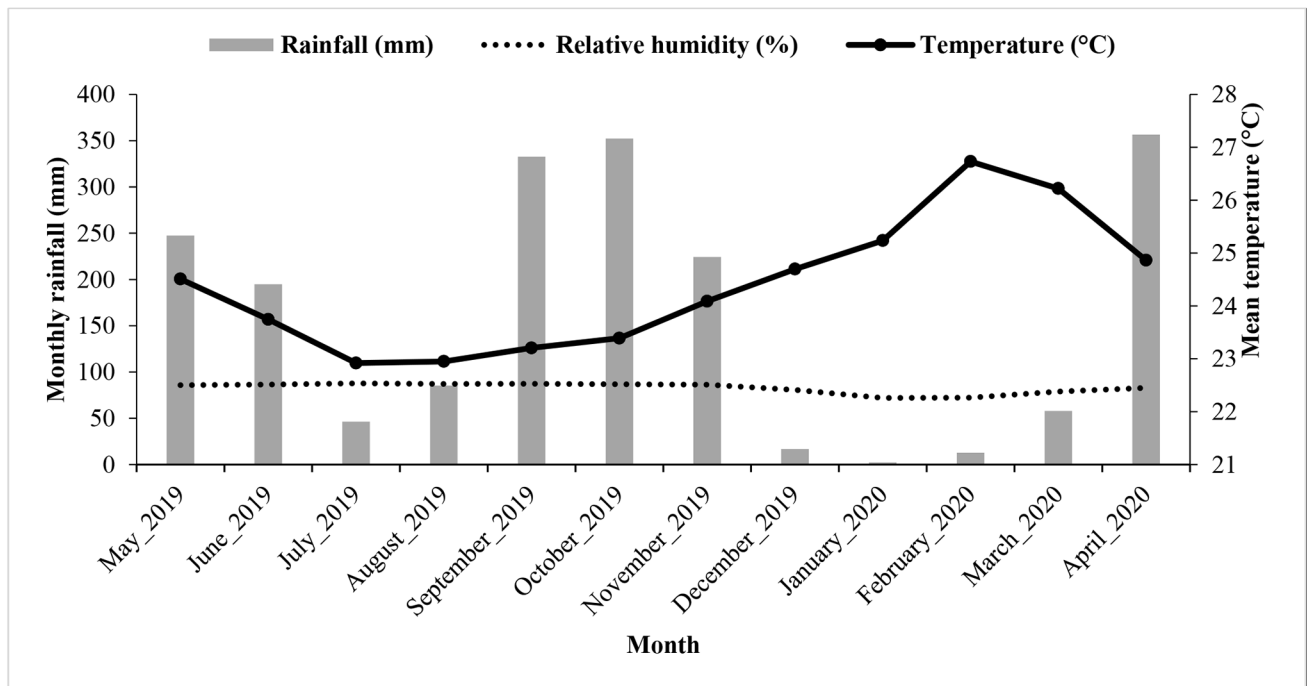
assess the linear relationship between temperature, relative humidity, rainfall, and the abundance of *C. megacephala*; (3) the Kruskal-Wallis H-test and the Mann-Whitney U-test to compare the relative abundance of *C. megacephala* between different collection sites and seasons.

The R software version 4.0.2 (packages “FactoMiner” and “Factoextra”) allowed us to carry out an PCA (expand) to evaluate the multiple relationships between the average temperature, relative humidity, daily precipitation, and the abundance of *C. megacephala* to determine the main climatic factors that govern the distribution of this species of fly.

The Excel software allowed us to calculate the frequency of occurrence (Fr) or the constancy of *C. megacephala* by the formula:  $Fr = f/F \times 100$ ; with  $f$  = number of catches where the fly is present and  $F$  = the total number of catches made during the study. To characterize the fidelity of *C.*

*megacephala* to the different habitats, we followed the classification of Dajoz (1982) ( $Fr > 50\%$ , the species is said to be constant in the environment;  $25\% \leq Fr \leq 50\%$ , the species is said to be incidental in the environment;  $Fr < 25\%$ , the species is said to be accidental in the environment). To assess the distribution of the species in the environment, several aggregation indices were used. These are:

- **The Fisher distribution index,  $I = s^2/m$**  (Fisher et al., 1922;). With  $s^2$  = variance and  $m$  = mean of fly individuals per catch.  $I <, =$  or  $> 1$ , correspond respectively to regular, random or aggregative spatial distributions. The test of  $\chi^2 = (n-1) I$  was used to testing the meaning of  $I$  when  $n < 30$ .  $n$  = number of sampling units. For  $n \geq 30$ , we calculate  $Z = \sqrt{2X^2} - \sqrt{2n - 3}$  and if  $|Z| > 1,96$ , the  $H_0$  hypothesis “distribution is random” at risk  $\alpha = 0,05$  is rejected (Canard and Poinso, 2004).



**Fig. 2** Umbrothermal diagram of the city of Yaoundé and its surroundings from May 2019 to April 2020. (source: Nkolbisson weather station in Yaoundé)

- **The Lexis index**,  $\lambda = \frac{s}{\bar{x}} = \sqrt{I}$  with  $s$  = standard deviation and  $\bar{x}$  = mean of individuals per catch.  $\lambda <, =$  or  $> 1$  correspond respectively to regular, random, or aggregative spatial distributions.
- **The Morisita distribution index**,  $I_d = n \frac{\sum x^2 - \Sigma x}{(\sum x)^2 - \Sigma x}$  with  $n$  = number and  $x$  = number of individuals per sample.  $I_d <, =$  or  $> 1$  correspond to regular, random, or aggregative spatial distributions, respectively (Morisita, 1962).
- **The Lefkovitch index**,  $L = \tan^{-1} \left( \frac{s^2}{\bar{x}} \right) - 1$  with  $s^2$  = variance and  $\bar{x}$  = mean fly individuals per catch. This index varies from  $-1$  to  $+1$ . For  $L = 0$ , the distribution is Poisson; if  $L < 0$ , the distribution tends towards regularity; and  $L > 0$  means the distribution tends towards aggregation (Lefkovitch, 1965).
- **The Neyman index**, given by the formula  $\frac{\bar{x}}{k}$  ou  $k = \frac{\bar{x}^2}{s^2}$  with  $x$  = sum of the statistical values. The lower the value of  $k$  is, the more the population of the species has an aggregative distribution; when  $k$  tends towards infinity, the distribution tends to approximate a random distribution (Neyman, 1939).
- **Taylor index**. Taylor showed that, for each species, there exists between the mean and the variance calculated from a series of samples of the same size a relationship of the form  $s^2 = a \left( \frac{\bar{x}}{b} \right)^b$ .  $b = \frac{\sum (X - \bar{X})(Y - \bar{Y})}{\sum (X - \bar{X})^2}$ , with  $Y = \log s^2$  and  $X = \log \bar{x}$ . If  $b < 1$ , the distribution is

regular; if  $b = 1$ , the distribution is random; if  $b > 1$ , the distribution is aggregate (Taylor, 1984).

- The QGIS software (version 3.4) allowed us to make the map of the city of Yaoundé showing the spatial distribution of the species according to the collection points.

For all comparisons made, all differences were assessed at the threshold value of  $P < 0.05$ .

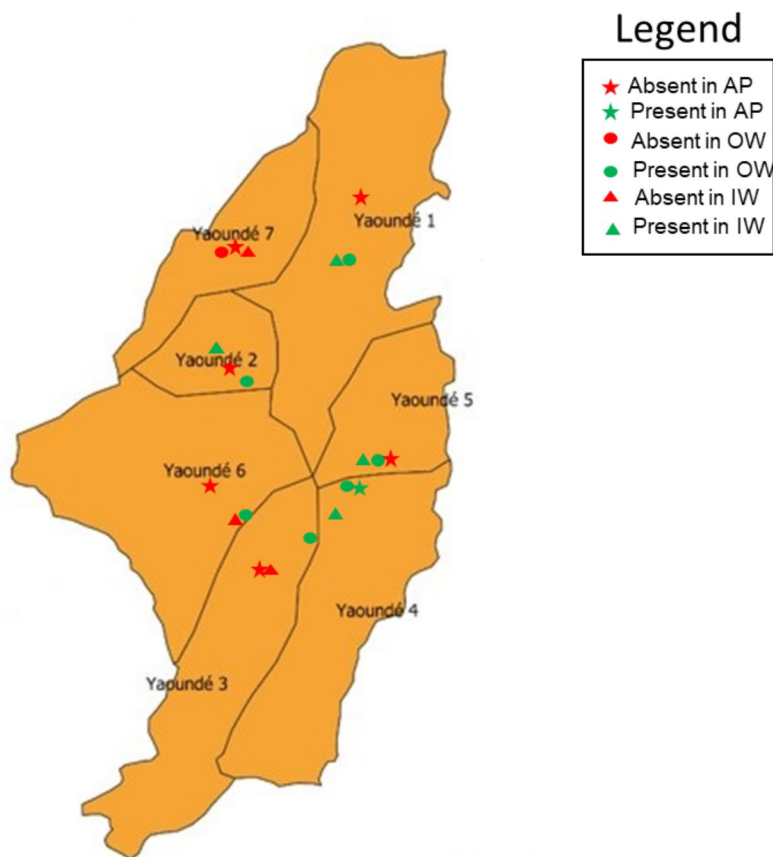
## Results and discussion

### Occurrence of *Chrysomya megacephala* in the city of Yaoundé

#### Spatial occurrence of *Chrysomya megacephala*

In the urban area of Yaoundé, *C. megacephala* was constant, incidental or accidental species (Fig. 3). It was incidental in spontaneous standings ( $25\% \leq Fr \leq 50\%$ ) and accidental in medium ( $Fr < 25\%$ ) and peri-urban standings ( $Fr < 25\%$ ) (Table 1). *Chrysomya megacephala* was incidental in organic waste ( $25\% \leq Fr \leq 50\%$ ) and accidental in inorganic waste ( $Fr < 25\%$ ), as well as in animal paddock ( $Fr < 25\%$ ). *Chrysomya megacephala* was constant only in mixed organic matter of spontaneous standings ( $Fr > 50\%$ ) (Table 1). This fidelity of *C. megacephala* to organic waste was also reported by Leong and Grace (2009) in urban

**Fig. 3** Spatial occurrence of *Chrysomya megacephala* in urban and peri-urban areas of Yaoundé



**Table 1** Occurrence of *Chrysomya megacephala* depending on the level of urbanization (standing) and the type of waste

Type of waste	Standing (level of urbanization)			Total
	Medium	Peri-urban	Spontaneous	
Mixed organic waste	8 (16,66%)	12 (33,33%)	25 (69,44%)	45 (40,83%)
Inorganic waste	5 (10,41%)	2 (5,55%)	2 (5,55%)	9 (8,67%)
Animal paddock	0 (0,0%)	0 (0,0%)	1 (2,77%)	1 (0,83%)
<b>Total</b>	13 (18,42%)	14 (17,56%)	28 (29,78%)	55 (45,83%)

NB: The values represent absolute occurrences and the values in parentheses represent the frequency of occurrence

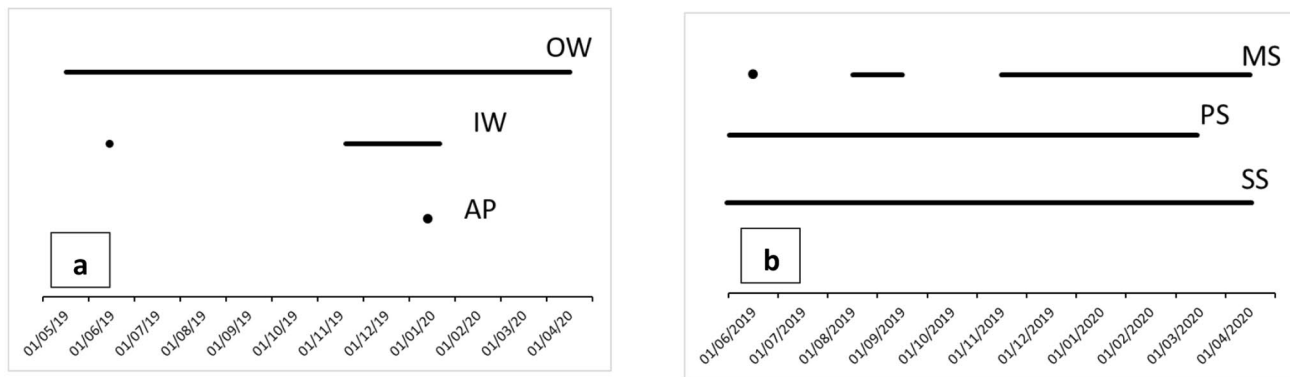
areas of Oahu Island, Hawaii, but with lower occurrences (10.0%). According to these authors, garbage containers remain an important source of fly production, particularly in garbage cans and dumpsters in apartment buildings. These results are explained by the fact that *C. megacephala* is closely associated with decaying organic matter in human environments (Badenhorst and Villet, 2018).

*Chrysomya megacephala* was more present in urban centers where the population is denser than in the suburbs of the city (Fig. 3). Since mixed organic matter is encountered

more towards the urban center, it exhibited higher occurrences than other types of waste. In addition, the occurrences of *C. megacephala* appear to be geographically more observed in the southern and eastern areas of the city compared to the western and northern areas where it was less present (Fig. 3).

**Temporal occurrence of *Chrysomya megacephala* in urban and peri-urban areas of Yaoundé**

In general, *C. megacephala* was present throughout the year in the city of Yaoundé. This general trend was mainly observed in mixed organic waste and spontaneous standings. However, the presence of this species was discontinuous in the medium standings with a notable absence in the periods June – August, and September – November; and in peri-urban standings with an absence during April only (Fig. 4b). Similarly, the presence of *C. megacephala* was discontinuous on inorganic waste with absences in the periods of May, June – November, and January – April, while it appeared only once in January in the animal paddock (Fig. 4a).



**Fig. 4** Temporal occurrence of *Chrysomya megacephala* at sites from May 2019 to April 2020 by waste type (a) and standing level (b)

**Table 2** Method of distribution of *Chrysomya megacephala* in the city of Yaoundé according to the level of standing and the type of waste

Repartition index	General	Type of standing			Type of waste		
		Medium	Peri-Urban	Spontaneous	Mixed organic waste	Inorganic waste	Animal paddock
<b>I de Fischer</b>	27,854**	26,721**	23,206**	31,627**	168,282**	43,269**	1,000
<b>Lexis</b>	5,277	5,169	4,817	5,624	12,972	6,578	1,000
<b>L de Lefkovitch</b>	0,534	0,533	0,528	0,539	0,565	0,548	-0,215
<b>k de Neyman</b>	26,854	25,721	22,206	30,627	167,282	42,269	--
<b>b de Taylor</b>	2,03	1,902	1,990	1,940	1,870	2,050	--
<b>Id de Morisita</b>	12,152	98,168	39,968	20,555	92,208	195,619	--

The vaues with two asterisks (\*\*) mean that the Ho hypothesis is accepted by excess of heterogeneity (strong aggregate distribution)

### Distribution pattern of *Chrysomya megacephala* in the city of Yaoundé

The various dispersal indices used to describe the distribution pattern of *Chrysomya megacephala* in the urban area of Yaoundé showed an overall aggregative distribution (Table 2). This aggregate distribution model was better described by the Fisher (27.8), Neyman (26.8), and Morisita (12.1) indices, compared to the other indices. This mode of distribution was also better described by the indices of Fisher, Lexis, Lefkovitch, and Neyman in the spontaneous standing, compared to the peri-urban standing where the aggregation was the lowest. The Taylor index better highlighted this mode of distribution in the peri-urban standing than in the medium standing; while the Morisita index showed the highest aggregation in the medium standing and lowest aggregation in the spontaneous standing.

Concerning the type of waste, mixed and inorganic waste showed an aggregative distribution while animal paddock showed either a random (Fisher and Lexis) or uniform (Lefkovitch) distribution. Comparison of the levels of aggregation between mixed and inorganic-organic waste showed that aggregation was higher in mixed organic waste according to the Fisher, Lexis, Lefkovitch, and Neyman indices. In inorganic matter, the Taylor and Morisita indices supported a high level of aggregation of *C. megacephala*.

The method of distribution of *C. megacephala* is generally of the aggregate type. These results corroborate those of Linsenmaier (1973), Keiding (1986), and Charabidzé (2008) which showed that flies have a gregarious instinct. The gregarious behavior of *C. megacephala* would be due to its ways of feeding, reproducing, and its females' looking for spawning sites. This aggregation is also specific to the level of urbanization and the type of waste encountered in the waste bin.

### The abundance of *Chrysomya megacephala* in the city of Yaoundé

We captured an average of 2.4 individuals at all collection sites for 30 min. This average abundance was significantly high in spontaneous standings ( $32.85 \pm 7.80$ ) and organic waste ( $45.62 \pm 10.25$ ). It was low in inorganic waste ( $4.78 \pm 3.37$ ), animal paddock ( $0.08 \pm 0.08$ ), medium standing ( $5.61 \pm 3.46$ ), and peri-urban standing ( $12 \pm 3.58$ ) (Table 3). These results are different to those obtained by Battan-Horenstein and Gleiser (2018) in Brazil. They described no difference between insect abundances in urban and peri-urban sites. In the work achieved by Sulaiman et al. (1988) in Malaysia on the role of certain Diptera as human helminth carriers, the authors showed that *C. megacephala* was the dominant species on waste dumps. The high abundance of *C. megacephala* in spontaneous standings and

**Table 3** Abundance of *Chrysomya megacephala* depending on the types of standing and waste

	Type of waste			Type of standing			Total
	Mixed organic waste	Inorganic waste	Animal paddock	Medium standings	Peri-urban	Spontaneous	
Population size	593 (90.4%)	62 (9.45%)	1 (0.15%)	73 (11.12%)	156 (23.8%)	427 (65.1%)	656
Mean ± SE	45,62 ± 10,25a	4,78 ± 3,37b	0,08 ± 0,08c	5,61 ± 3,46a	12 ± 3,58a	32,85 ± 7,80b	2,4 ± 0,49
Range	0–278	0–52	0–1	0–43	0–44	0–65	0–65

Values in parentheses indicate the values of relative abundances. Identical letters indicate non-significant differences

organic wastes could be related to the high distribution of spontaneous standings and organic waste bins which are rich in detritus or decayed organic materials, and the strong attractiveness of decaying organic matter for diptera. This result simply confirms the strong attractiveness of decaying organic matter for *C. megacephala*. In fact, in calliphorid Diptera, the larvae feed mainly on decaying organic matter Charabidzé (2008). Laurence (1988) observed the immature development of *C. megacephala* in large numbers in the garbage. According to Williams and Villet (2019), the abundance of *C. megacephala* could be due to the proximity of the city's landfill, insufficient sanitary conditions and health education could also favor the development and increase abundance of *C. megacephala* in spontaneous standings, favoring the transmission of fecal-oral diseases. Indeed, the fact that *C. megacephala* is more present in the spontaneous standings of the city of Yaoundé could be due to the level of sanitation of the city neighborhoods. Indeed, in the spontaneous standings, the standard of living of the population is very low and most of the inhabitants would meet strong economic difficulties. This will have an impact on the level of sanitation in this area.

Overall, *Chrysomya megacephala* was significantly abundant during the long dry season in mixed organic waste (57.20) and during the long rainy season in inorganic waste (14.66) (Fig. 5a). This effect of seasonality was not significant in animal husbandry sites (on animal paddock). This seasonal fluctuation in the abundance of *C. megacephala* was also significant in the different types of standings (level of urbanization). The peak of abundance was observed during the short rainy season in the spontaneous standing (37.50), during the long rainy season in the medium standing, and during the long dry season in the peri-urban standing. (Fig. 5b). Although the study did not assess the biomass or the waste size at each study point, this work could be achieved to establish the link between insect relative abundance and waste quantity or biomass.

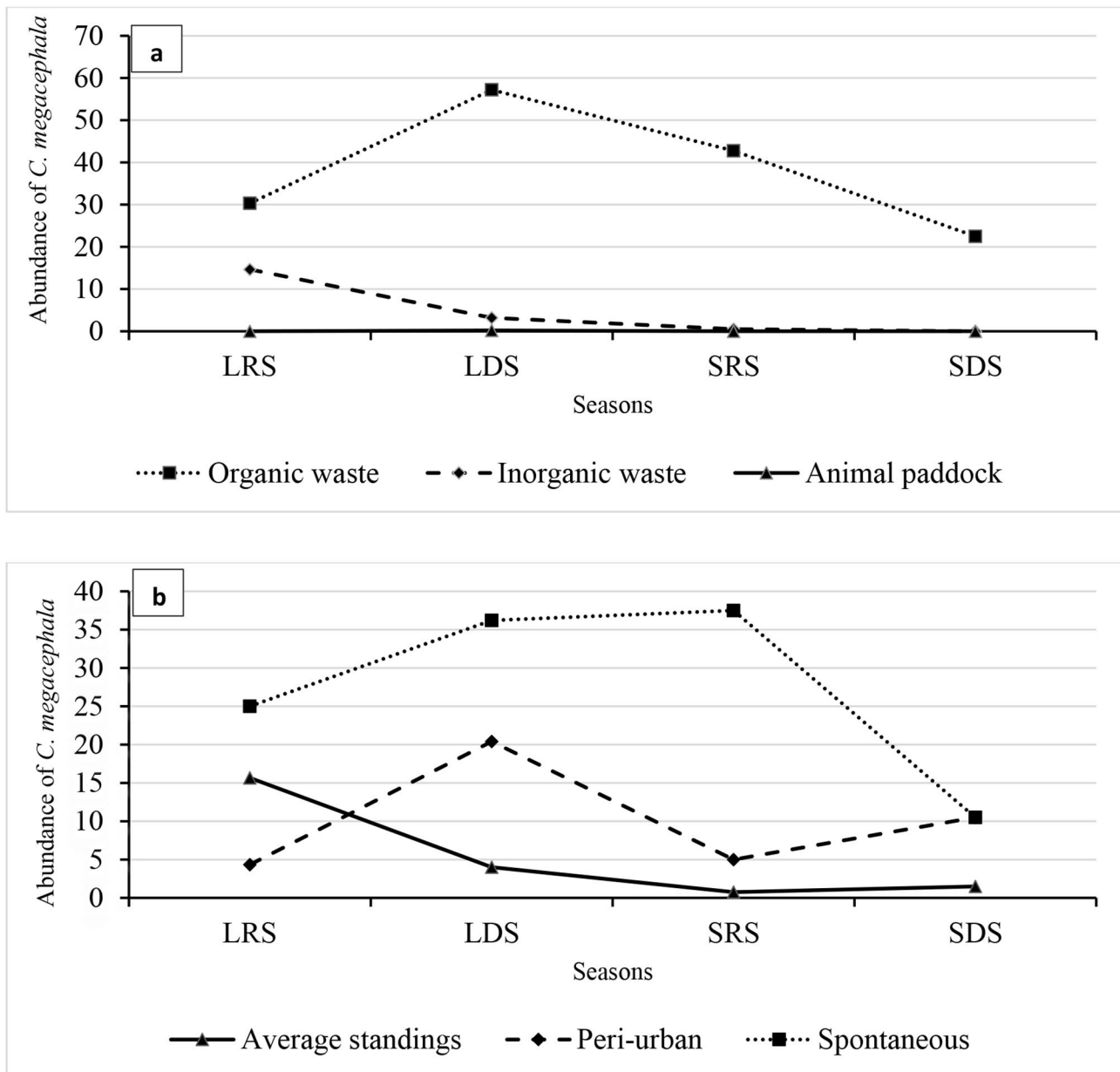
In general, *Chrysomya megacephala* was present throughout the year in the urban areas of Yaoundé. These results are similar to those obtained by Sontigun et al. (2018), Ngoen-Klan et al. (2011), in Thailand, and Kavazos and Wallman (2012) in Australia. This general trend was observed in waste consisting mainly of organic matter and in spontaneous standings. Similarly, Badenhorst and Villet

(2018) have found that *C. megacephala* is closely associated with decaying organic matter in human environments. Indeed, the abundance of *C. megacephala* is affected by seasonality as our results showed. The high abundances were during the large dry season and the short rainy season. Similar results were reported in Thailand by Sontigun et al. (2018) who found out that the highest abundance of *C. megacephala* was in summer. In contrast, Phasuk et al. (2013) observed that *C. megacephala* had three statistical peaks with the highest abundance was in January followed by September and June. Thaddeus et al. (2005) suggested that the outbreaks and cases of diarrheal diseases of food origin in urban and rural areas are closely related to the seasonal increase in the abundance of garbage flies.

### Influence of climatic factors on the fly abundance

We noted that peaks in abundance appeared either before or after heavy precipitation (Fig. 6). In addition, the increase in relative humidity coupled with the decrease in temperature was associated with a significant decrease in the population of *C. megacephala* (Fig. 6). However, the Spearman correlation test showed that the linear relationship is non-significant between: abundance and temperature ( $r_s = 0.53$ ;  $p = 0.07$ ), abundance and relative humidity ( $r_s = -0.55$ ;  $p = 0.06$ ) and abundance and precipitation ( $r_s = -0.29$ ;  $p = 0.35$ )., These results concur with findings of Bong and Zairi (2010) who found as us no significant correlation between the abundance of flies and climatic factors. Those findings contrast with those of Guimarães and Papavero (1999), Pujol-Luz et al. (2008), Ngoen-Klan et al. (2011), Azevedo and Krüger (2013) and Sontigun et al. (2018) for which species of the genus *Chrysomya* tend to increase their abundance with the temperature. Considering the seasonal variation of *C. megacephala* in the different types of waste, we find that variation in temperature, relative humidity, and precipitation did not have a significant effect on the abundance and seasonal fluctuations of the species. This shows that climate is not the only limiting factor. Waste types may consist of deep microhabitats, thus favoring the proliferation of *C. megacephala*.

Based on principal component analysis, the main component showed that temperature, relative humidity, and rainfall strongly influenced *C. megacephala* populations according

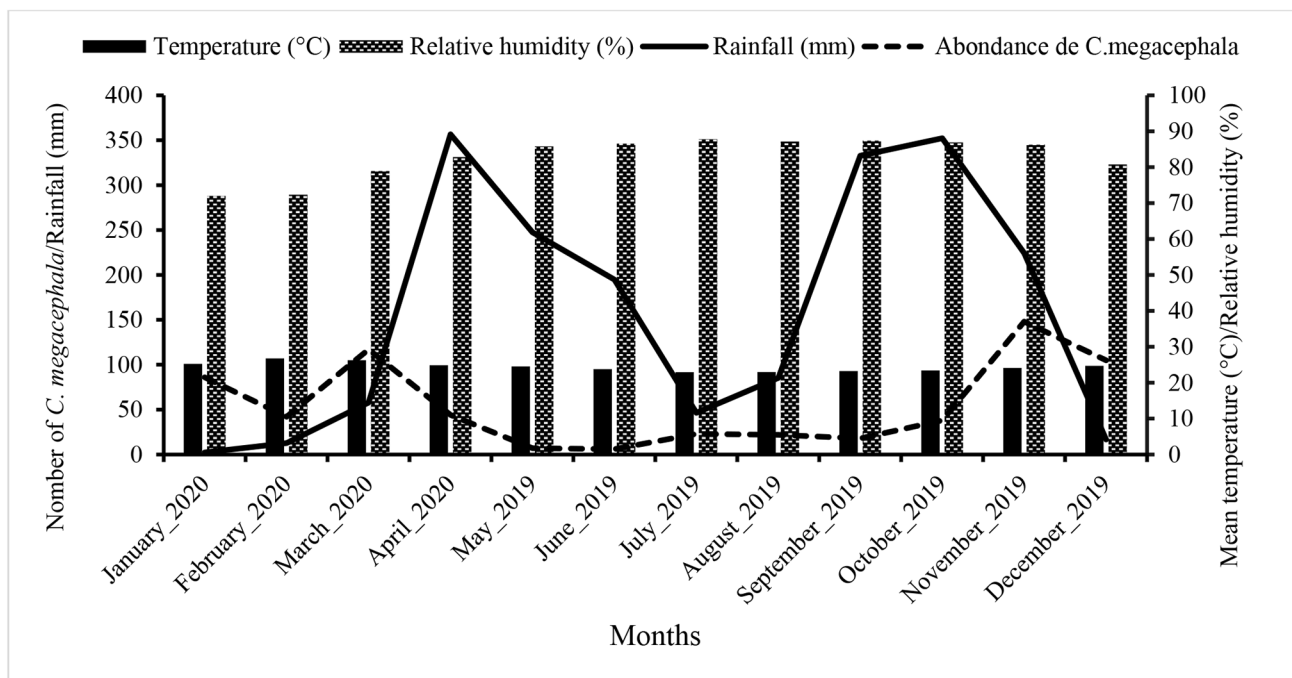


**Fig. 5** Seasonal fluctuations of *Chrysomya megacephala* depending on the type of waste (a) and the level of standing (b)

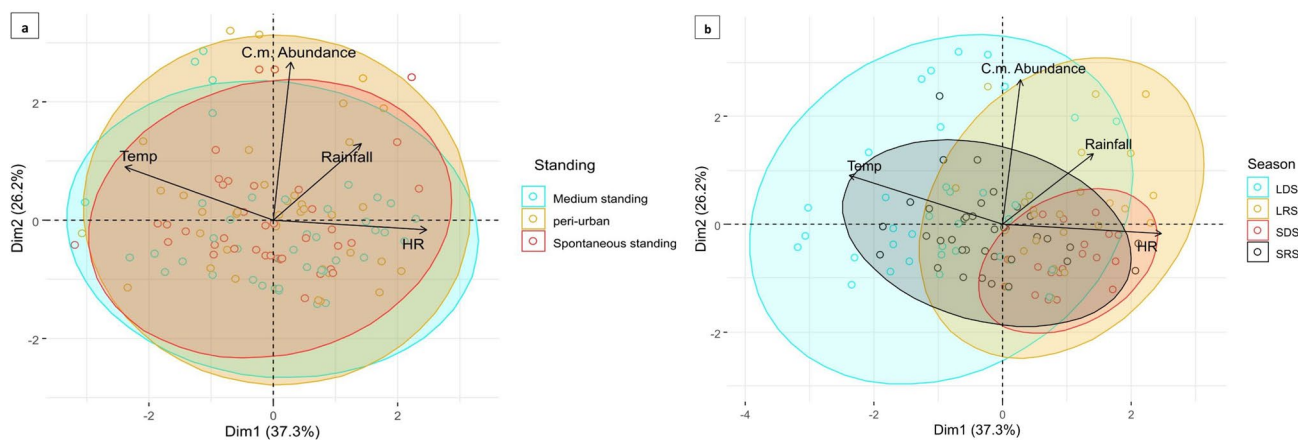
to the different seasons, but the populations of the standings (level of urbanization) remained relatively homogeneous (Fig. 7a and b). Populations in the long dry season had the highest and lowest abundances (high variance of the data) and were strongly affected by temperature. Populations in the great rainy season were more affected by rainfall. Populations in the small rainy season had medium abundances but were strongly influenced by temperature while populations in the small dry season had a high affinity with relative humidity.

## Conclusion

The accumulation areas of organic waste in the city of Yaoundé are suitable sites for the multiplication of *C. megacephala*. The presence of *C. megacephala* would represent a risk of mechanical transmission of infective diseases in all sites except in the high places of the city of Yaoundé where it would be seasonal. The indices of Fisher, Neyman, and Morisita are those that best described the aggregative distribution of this insect. *C. megacephala* is present throughout the year in spontaneous standings and organic waste with a maximum abundance during the short rainy season. Better



**Fig. 6** Influence of temperature, relative humidity, and rainfall on *Chrysomya megacephala* abundance



**Fig. 7** Principal analysis biplot of *Chrysomya megacephala* abundance with climatic parameters as explanatory variables. The grouping of points was done according to the type of standing (a) and the season

(b). The Dim1 and Dim2 components expressed 37.3% and 26.2% of the explanatory variables respectively LRS: long rainy season; LDS: large dry season, SRS: short rainy season; SDS: short dry season

waste management in the city of Yaoundé can be an important part of the insect’s control.

A sustainable practice of garbage collection in the urban areas of Cameroon may be essential in the search for strategies to control the reproduction and proliferation of this fly.

**Acknowledgements** We thank the *Plant and Animal Protection Team* for their assistance in data collection and statistical analysis.

**Author Contribution** GSL carried out the data collection, analyzed the data wrote the manuscript. DTC analyzed the data and made the figures. BH read and corrected the article, MNA helped with the data collection in the field, KS supervised the work, help with data analysis

and writing of the article.

**Funding** No funding was received for this study.

**Declarations**

**Competing interests** The authors have no relevant financial or non-financial interests to disclose.

**Conflict of Interest** The authors declare that they have no conflict of interest.

## References

- Alikhan, M., K. Al Ghamdi, J. A. Mahyoub, and N. Alanazi. 2018. Public health and veterinary important flies (order: Diptera) prevalent in Jeddah Saudi Arabia with their dominant characteristics and identification key. *Saudi journal of biological sciences*.25:1648–1663
- Azevedo, R. R., and R. F. Krüger. 2013. The influence of temperature and humidity on abundance and richness of Calliphoridae (Diptera). *Iheringia. Série Zoologia*.103:145–152
- Badenhorst, R., and M. H. Villet. 2018. The uses of *Chrysomya megacephala* (Fabricius, 1794) (Diptera: Calliphoridae) in forensic entomology. *Forensic Sciences Research*. 3:2–15
- Battan-Horenstein, M., and R. M. Gleiser. 2018. Necrophagous flies assemblages: Spatio-temporal patterns in a neotropical urban environment. *Caldasia*.40:296–309
- Bohart, G. E., and J. L. Gressitt. 1951. Filth-inhabiting flies of Guam
- Bong, L. J., and J. Zairi., 2010. Temporal fluctuations of insecticides resistance in *Musca domestica* Linn (Diptera: Muscidae) in Malaysia. *Tropical Biomedicine*.27:317–325
- Canard, A., and D. Poinsot. 2004. Quelques méthodes statistiques typiques de l'étude des populations et des peuplements par la méthode des quadrats. *Fiche technique*, Université de Rennes1,34p
- Castellani, A., and A. J. Chalmers. 1919. *Manual of tropical medicine*. Baillière, Tindall and Cox
- Chaiwong, T., T. Srivoramas, K. O. M. Sukontason, M. R. Sanford, and K. L. Sukontason. 2012. Bacterial fauna associated with the blow fly, *Chrysomya megacephala* (F.) in Ubon Ratchathani Province of Northeast Thailand. *International Journal of Parasitology Research*. 4:71
- Charabidzé, D. 2008. Etude de la biologie des insectes nécrophages et application à l'expertise en entomologie médico-légale (PhD Thesis)
- Chester, F. D. 1901. *A manual of determinative bacteriology*. Macmillan Company
- Dajoz, R. 1982. Précis d'écologie. Écologie fondamentale et appliquée
- Feugang, Y. F. D., E. de Coninck, F. Hubrecht, Y. Braet, L. Bourguignon, B. C. F. Bilong, A. J. C. Ateba, and C. Djiéto-Lordon. 2012. First records on five species of Calliphoridae (Diptera) reared from maggot collected on rat carrions corpse during a forensic entomology experiment in the campus of the University of Yaounde I-Cameroon. *International Journal of Biosciences (IJB)*. 2:75–80
- Fisher, R. A. 1922. On the interpretation of  $\chi^2$  from contingency tables, and the calculation of P. *Journal of the Royal Statistical Society*.85:87–94
- Guimarães, J. H., and N. Papavero. 1999. Myiasis in man and animals in the Neotropical Region: bibliographic database. *Plêiade*
- Irish, S., T. Lindsay, and N. Wyatt. 2014. Key to adults of afrotropical species of the genus *Chrysomya* Robineau-Desvoidy (Diptera: Calliphoridae). *African Entomology*.22:297–306
- Kavazos, C., and J. Wallman. 2012. Community composition of carrion-breeding blowflies (Diptera: Calliphoridae) along an urban gradient in south-eastern Australia. *Faculty of Science - Papers (Archive)*.183–190
- Keiding, J. 1986. The house-fly: biology and control (No. WHO/VBC/86.937. Unpublished). World Health Organization
- Kurahashi, H., and A. H. Kirk-Spriggs. 2006. The Calliphoridae of Namibia (Diptera: Oestroidea). *Zootaxa*.1322:1–132
- Laurence, B. R. 1988. The tropical African latrine blowfly, *Chrysomya putoria* (Wiedemann). *Medical and Veterinary Entomology*. 2: 285–291
- Lefkovich, L. P. 1965. The study of population growth in organisms grouped by stages. *Biometrics*.1–18
- Linsenmaier, W. 1973. *Insectes du monde: trad. de l'anglais par une équipe d'entomologistes du muséum national d'histoire naturelle*. Stock
- Lutz, L., K. A. Williams, M. H. Villet, M. Ekanem, and K. Szpila. 2018. Species identification of adult african blowflies (Diptera: Calliphoridae) of forensic importance. *International journal of legal medicine*.132:831–842
- Migula, W. 1895. Die Natürlichen Pflanzenfamilien nebst ihren Gattungen und wichtigeren Arten, insbesondere den Nutzpflanzen, unter Mitwirkung zahlreicher hervorragender Fachgelehrten begründet - Biodiversity Heritage Library. (<https://www.biodiversitylibrary.org/bibliography/4635>)
- Migula, W. 1900. *System der bakterien: bd. Spezielle systematik der bakterien*. G. Fischer
- Morisita, M. 1962. I  $\sigma$ -Index, a measure of dispersion of individuals. *Researches on population ecology*. 4:1–7
- Neyman, J. 1939. On a new class of "contagious" distributions, applicable in entomology and bacteriology. *The Annals of Mathematical Statistics*.10:35–57
- Ngambi, J. R. 2015. Déchets solides ménagers de la ville de Yaoundé (Cameroun): de la gestion linéaire vers une économie circulaire (PhD Thesis)
- Ngoen-Klan, R., K. Moophayak, T. Klong-Klaew, K. N. Irvine, K. L. Sukontason, C. Prangkio, P. Somboon, and K. Sukontason. 2011. Do climatic and physical factors affect populations of the blow fly *Chrysomya megacephala* and house fly *Musca domestica*? *Parasitology Research*. 109:1279–1292
- Phasuk, J., T. Tharawoot, and J. Chanpaisaeng. 2013. Seasonal abundance of blow flies (Diptera: Calliphoridae) in three urban parks of Bangkok, Thailand. *Agriculture and Natural Resources*.47:828–834
- Pujol-Luz, J. R., L. C. Arantes, and R. Constantino. 2008. Cem anos da entomologia forense no Brasil (1908–2008). *Revista Brasileira de Entomologia*.52:485–492
- Rosenbach, F. J. 1884. *Mikroorganismen bei den Wundinfektions-Krankheiten des Menschen Wiesbaden*. JF Bergmann's Verlag
- Schroeter, J. 1872. Über einige durch Bacterien gebildete Pigmente, p109–126. *Beitrage zur Biologie der Pflanzen*. JU Kern's Verlag, Breslau, Berlin, Germany
- Sighomnou, D. 2004. Analyse et redéfinition des régimes climatiques et hydrologique du Cameroun: perspectives d'évolution des ressources en eau. (PhD Thesis)
- Sontigun, N., K. L. Sukontason, T. Klong-klaew, S. Sanit, C. Samerjai, P. Somboon, S. Thanapornpoonpong, J. Amendt, and K. Sukontason. 2018. Bionomics of the oriental latrine fly *Chrysomya megacephala* (Fabricius) (Diptera: Calliphoridae): temporal fluctuation and reproductive potential. *Parasites Vectors*.11:415
- Srivoramas, T., T. Chaiwong, and M. R. Sanford. 2012. Isolation of fungi from adult house fly, *Musca domestica* and the blow fly *Chrysomya megacephala* in Ubon Ratchathani province, north-eastern Thailand. *Int J Parasitol Res*.4:53–6
- Stanier, R. Y. 1943. A note on the taxonomy of *Proteus hydrophilus*. *Journal of bacteriology*.46:213–214
- Sukontason, K. L., M. Bunchoo, B. Khantawa, S. Piangjai, Y. Rongsriyam, and K. Sukontason. 2007. Comparison between *Musca domestica* and *Chrysomya megacephala* as carriers of bacteria in northern Thailand. *Southeast Asian Journal of Tropical Medicine and Public Health*.38:38
- Sulaiman, I. M., E. Jacobs, S. Simpson, and K. Kerdahi. 2017. Identification of 18 vector species belonging to Group I, Group II, and Group III 'Dirty 22' species known to contaminate food and spread foodborne pathogens: DNA barcoding study of public health importance. *Int J Trop Insect Sci*.37:1–10
- Sulaiman, S., A. R. Sohadi, H. Yunus, and R. Ibrahlim. 1988. The role of some cyclorrhaphan flies as carriers of human helminths in Malaysia. *Medical and Veterinary Entomology*. 2:1–6

- Taylor, G. J. 1984. Alexithymia: concept, measurement, and implications for treatment. *The American journal of psychiatry*
- Thaddeus K. Graczyk, R. Knight, and L. Tamang. 2005. Mechanical transmission of human protozoan parasites by insects. *Clinical microbiology reviews*.18:128–132
- Trevisan, V. 1887. Sul Micrococco della rabbia e sulla possibilità di riconoscere durante il periodo d'incubazione, dall'esame del sangue della persona moricata, se ha contratta l'infezione rabbica. *Rend Ist Lombardo Accad Sci Lett Sez (ser.2)*. 20:88–105
- Warren, S. H., and W. M. Scott. 1930. A new serological type of *Salmonella*. *Epidemiology & Infection*.29:415–417
- Wells, J. D. 1991. *Chrysomya megacephala* (Diptera: Calliphoridae) has reached the continental United States: review of its biology, pest status, and spread around the world. *Journal of Medical Entomology*.28:471–473
- Williams, K. A., and M. H. Villet. 2019. Spatial and seasonal distribution of forensically important blow flies (Diptera: Calliphoridae) in Makhanda, Eastern Cape, South Africa. *Journal of Medical Entomology*.56:1231–1238
- Yasmeen, S., and M. Amir. 2022. Ultrastructural, histochemical, and biochemical damage induced by chlorpyrifos in the midgut of *Chrysomya megacephala* larvae after acute exposure. *Int J Trop Insect Sci*.42:3793–3806
- Leong, M. K., and J. K. Grace. 2009. Occurrence and distribution of flies (Diptera: Calliphoridae and Muscidae) of public health importance on the island of Oahu.

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.