American Journal of Entomology
2022; 6(3): 49-71
http://www.sciencepublishinggroup.com/j/aje
doi: 10.11648/j.aje.20220603.11
ISSN: 2640-0529 (Print); ISSN: 2640-0537 (Online)

Biodiversity, Abundance of Flies (Diptera: Brachycera) Attracted by Fresh Flesh and Identification of Medical or Forensic Important Species in Douala (Cameroon)

Romaine Magloire Fantio, Edith Laure Kenne, Andrea Sahara Kenne Toukem, Sedrick Junior Tsekane, Patrick Steve Tuekam-Kowa, Abdel Kayoum Yomon, Stevie Ange Tanekeng Tsayem, Martin Kenne*

Department of Biology and Physiology of Animal Organisms, Faculty of Science, University of Douala, Douala, Cameroon

Email address:

fantioromainemagloire12@yahoo.com (R. M. Fantio), edithlaure.kenne@yahoo.fr (E. L. Kenne), andreakenne160@gmail.com (A. S. K. Toukem), stsekane@yahoo.com (S. J. Tsekane), tukopast@gmail.com (P. S. Tuekam-Kowa), abdelkayoumyomon@yahoo.fr (A. K. Yomon), ange.tsayem@yahoo.com (S. A. T. Tsayem), medoum68@yahoo.fr or martin.kenne@univ-douala.cm (M. Kenne)

*Corresponding author

To cite this article:

Romaine Magloire Fantio, Edith Laure Kenne, Andrea Sahara Kenne Toukem, Sedrick Junior Tsekane, Patrick Steve Tuekam-Kowa, Abdel Kayoum Yomon, Stevie Ange Tanekeng Tsayem, Martin Kenne. Biodiversity, Abundance of Flies (Diptera: Brachycera) Attracted by Fresh Flesh and Identification of Medical or Forensic Important Species in Douala (Cameroon). *American Journal of Entomology*. Vol. 6, No. 3, 2022, pp. 49-71. doi: 10.11648/j.aje.20220603.11

Received: June 27, 2022; **Accepted**: July 12, 2022; **Published**: July 20, 2022

Abstract: In tropical countries some non-biting flies alone or in combination cause myiasis infections. Nowaday, myiasis cases are increasing in urban and rural areas but nothing is known concerning the composition and structure of the responsible flies' assemblages. Our study aimed to establish a baseline of information on the distribution of non-biting flies in the urban quarters of Douala (Littoral-Cameroon), as a first step in evaluating their status. Ecological surveys were conducted in 2020 during the rainy season (July to November) in four quarters of Douala (populous residential quarter Bilongué, Ndakat market, Ndogbong university campus, and Souboum health center). Flies were captured and stored in vials containing 70° alcohol, identified and the community stucture was characterized. A total of 7,379 flies belonged to four families, five subfamilies, seven genera and 14 species. Calliphoridae was the most represented family (86.2%) followed by Muscidae (13.0%) and Sarcophagidae (0.7%) while Fanniidae was rare (0.1%). These flies were facultative myiasigenic species. We identified three Afrotropical species (21.4%), nine exotic species (64.3%) and two unknown-origin species (14.3%). Flies of high abundances were the Afrotropical-origin fly *Chrysomyia putoria* Wiedemann, 1830 (Calliphoridae: Chrysomyiinae; 36.8% of the total collection), the Australasian-origin fly *Ch. rufifacies* Macquart, 1842 (Calliphoridae: Chrysomyiinae; 21.8%), the unknown origin fly *Lucilia* spp. (Calliphoridae: Calliphorinae; 18.2%), the Holarctic-origin fly *Phormia regina* Meigen, 1826 (Calliphoridae: Chrysomyiinae; 8.2%), the Paleartic-origin fly *Musca (Musca) domestica* Linnaeus, 1758 (Muscidae: Muscinae; 7.6%), the Paleartic-origin fly *Muscina. pabulorum* Fallen, 1817 [=*Muscina prolapsa* Harris, 1780] (Muscidae: Muscinae; 3.0%) and the Palearctic-origin fly *Musca autumnalis* De Geer, 1776 (Muscidae: Muscinae; 1.8%). Seven rare species were represented each by less than 1.0% of the overall collection. Overall, species exhibited a positive asociation (Schluter's ratio: VR = 1.913, Statistic: W = 397.90, df = 14, $p < 0.001$). Assemblages exhibited high evenness, low species richness and diversity and moderate dominance by a few species, suggesting a moderate interspecies competition influence and/or disturbance by human activities. GM model fitted SAD from Ndogbong, Bilongué, Souboum and the global assemblage, confirming these assemblages are dominated by a few species (pioneer assemblages) and operated according to niche partitioning strategy. LN model fitted the SAD from Ndakat market, suggesting a community where the majority of species showed moderate abundances, close to the model of little disturbed environments. The high occurence of myiasigenic flies necessitates the reaction of the public health control service to reduce myiasis occurrence in the city.

Keywords: Flies, Biodiversity, Myiasigenic Species, Douala (Cameroon)

1. Introduction

Flies are the most diverse insects present in all ecosystems. In terrestrial ecosystems they are particularly abundant in antropized environments such as inside homes [1-4], hospitals, food centers and breeding farms [4-7], gardens and plantations [8-10], markets and factories [4, 11]. Most synanthropic flies belong to the order Diptera Linnaeus, 1758 and the sub-order Brachycera Schiner, 1862. Adults of Brachycera flies present short three-segmented antennae, the last segment bearing a long bristle (arista), or a multisegmented style. Among the Brachycera flies, the infra-order Cyclorrhapha Brauer, 1863 recruits the most evolved species, with maggot-like larvae and the pupae (nymphal stage) often barrel-shaped. The diet of Cyclorrhapha flies is diversified including pollinators [12], predators [13-17], parasitoïds in their larval stage of other insects including agricultural and forestry pests [18, 19], phytophagous species are those damaging fruits and responsible of yield loss [20], saprophytic species feed mainly on rotting fruits and remains and decaying organic mater including household waste, human and animal faeces [21, 22], necrophagous species are of forensic importance since they feed mainly on food scraps and remains [23]. Saprophytic and necrophagous species (also called decomposers) play an important ecological role in the recycling of plant and animal organic matter in the ecosystems [24]. Other species could transmit human and livestock diseases agents such as protozoa [*Entamoeba coli* Grassi, 1879, *E. histolytica* Schaudinn, 1903], fungi (*Candida* Berkhout 1923, *Aspergillus* P. Micheli ex Link 1809, and *Penicillium* Link 1809), viruses (Senecavirus A and Ebola virus), bacteria [*Escherichia coli* Escherich 1885 and *Pseudomonas aeruginosa* Schroeter, 1872], as well as helminths (*Ascaris lumbricoides* Linnaeus 1758 and *Taenia* Linnaeus, 1758), behaving as mechanical vectors [25-27].

1.1. Literature Review

Among important species in public and veterinary health, larvae of obligatory myiasigenic species do develop exclusively in the live flesh of humans and cattle, causing furuncular infections [23, 28, 29]. This is the case of the Calliphoridae Hough, 1899 **[**the New-world screwworm *Cochliomyia hominivorax* Coquerel, 1858 and the old-world screwworm *Chrysomya bezziana* Villeneuve, 1914**]**, the case of botflies Oestridae Leach, 1815 [Human bot flies *Dermatobia hominis* Linnaeus, 1781, Horse bot flies *Gasterophilus intestinalis* De Geer, 1776, Warble flies *Hypoderma bovis* Linnaeus, 1758*,* northern cattle grub *H. lineatum* Villers, 1789 and sheep botflies *Oestrus ovis* Linnaeus, 1758] and Sarcophagidae Haliday, 1853 [case of the flesh flies *Wöhlfartia magnifica* Schiner, 1862] [30-33]. Facultative myiasigenic species occasionally cause semi-specific myiasis in which fly larvae develop either in living tissue or in decaying organic matters [34]. These opportunistic myiasigenic flies attack filthy infected wounds, stimulated by the odour and do not attack clean wounds or intact skin. Examples of these flies are the Bluebottle flies *Calliphora* spp., Greenbottle flies *Lucilia* spp., flesh flies *Sarcophaga* spp., cheese skipper fly *Piophila casei* and rat-tailed maggot flies *Tubifera tenax* [31, 33]. The pseudo- or accidental myiasis producers are flies with free-living non-parasitic larvae accidentally swallowed by humans or livestock or even in direct contact with them, causing characteristic myiasis (false myiasis) [28]. Nowadays, Diptera includes more than 167,584 described species among which 146,206 living species and 3,793 extinct species, making a total of 149,999 species belonging to 235 families, 494 subfamilies and 10,650 genera [35]. According to the same source of information, approximately 17,585 specimens are in the process of confirmation of identification. About 14 families of the Diptera order compress all obligatory, facultative and accidental myiasigenic species [29-31, 33, 36-49]. These families are Calliphoridae Hough, 1899, Cuterebridae Brauer, 1887, Drosophilidae Loew, 1862, Dryomyzidae Schiner, 1862, Gasterophilidae Girschner, 1896, Muscidae Latreille, 1802, Oestridae Leach, 1815, Phoridae Curtis, 1833, Piophilidae Macquart, 1835, Psychodidae Newman, 1834, Sarcophagidae Haliday, 1853, Scenopinidae Burmeister, 1835, Stratiomydae Latreille 1802 and Syrphidae Latreille, 1802. Flies of the Muscidae family are mostly cited in false myiasis. To these 14 myiasigenic families, Bhagat [38] added three families that larvae live as scavengers in various kinds of decaying organic matter [Acroceridae Leach, 1815, Anisopodidae Knab, 1912 and Fanniidae Schnabl & Dziedzicki, 1911]. Among these myiasigenic flies, four families are the most important: Calliphoridae, Oestridae (all species in their larval stages), Sarcophagidae and Muscidae [28, 50]. Sarcophagidae and Calliphoridae both recruit about 80 myiasigenic species [29]. Human myiasis is a tropical and subtropical neglected disease, rare in developed countries, possibly under-reported, where it appears mostly in cattle and tourists returning from the tropics and subtropics of the world [51-54]. It is commonly recorded in domestic and wild animals but occurs rarely in humans [36, 55].

1.2. Problem and Objectives

Common risk factors for myiasis among humans are increasing fly populations, advanced age, poor nutrition, social isolation, poor hygienic conditions, open neglected wounds, smelling discharge from natural body openings and the presence of domestic animals in the close vicinity [36]. In Africa, the community structure of flies important to humans and livestock health, is largely reported in Mediterranean regions such as mountain region and Kabylia region (North-central Algeria) and Egypt [5, 56, 57]. But it is under-

reported in African sub-Saharan countries [58]. In Central African countries, available published reports are focused on the occurrence of few myiasigenic flies in rural localities and livestock farms as is the case at the Jos Museum Zoological Garden and at the Old Oyo National Park (Nigeria) [59, 60]. But no information is available concerning the global flies' community structure. In Cameroon, recent studies conducted in rural areas of the western highlands have shown that the Calliphoridae *Cordylobia anthropophaga* (Blanchard & Berenger-Feraud, 1872) was the main parasites occurring in domestic cavies, the prevalence of myiasis in animals being 2.8%, myiasis were recorded in 2.0% and 4.3% animals in Menoua and Bamboutos divisions, respectively [61, 62]. According to the same authors 11 farms (8·95%) were infested with *Co. anthropophaga* with 6.4% and 13.3% of farms in the Menoua and Bamboutos divisions, respectively. The investigations of Sevidzem et al. [63, 64] showed that the rangelands of the Adamawa Plateau (North-Cameroon) are densely infested with five species of Stomoxyinae (*Stomoxys niger niger* Macquart 1851, *St. calcitrans* (Linnaeus, 1758), *St. niger bilineatus* Grünberg 1906, *St. omega* Newstead, Dutton & Todd 1907, and *St. xanthomelas* Roubaud, 1937), the highest apparent density being recorded in Galim locality (30 stomoxyines/trap/day) but little is known about the community structure of medically or veterinary important flies in urban areas except the report from Yaoundé where cases of *Co. rodhaini* Gedoelst 1910 myiasis have been declared [65]. Non-biting flies colonize almost all rural and urban localities in Cameroon and among them myiasigenic species are present, as is the case in all topical and subtropical countries. However the control of pest flies is one of the major constraints to be overcome in public health. In the populous quarters of Douala, cases of myiasis are on the rise due to the accumulation of household waste in the streets, the derisory environmental hygiene, the incivility and the promiscuity of the populations, producing a situation favourable to the explosion of myiasigenic fly species. The aim of our study is to determine the biodiversity of flies in the urban areas of Douala (Littoral-Cameroon) and identify potential species of medical or veterinary importance. This information is essential for the preventive fight against myiasis occurrence in humans and domestic animals.

2. Materials and Methods

2.1. Study Sites

Field collections were conducted in 2020 during the rainy season (July to November). Collection sessions were carried out in four urban quarters of the Douala city (Littoral-Cameroon) (5°30′04″N, 10°14′30″E; altitude: 1,442 meter a.s.l). These localities were: the very populous residential quarter named Bilongué (4°01′20.35″N, 9°44′11.91″E) where there is a strong promiscuity of the population, Ndakat market located in Ndokoti (4°02′39.60″N, 9°44′43.31″E) where incivility and anarchy reign in the occupation of space and waste management, Ndogbong university campus (4°03′28.72″N, 9°44′31.37″E) where we checked the risk of infection of students with myiasis knowing that the campus is surrounded by unsanitary areas of the city, and the Souboum health center (4°01′3.53″N, 9°44′1.60″E) also surrounded by populous unsanitary areas, where we checked the risk of nosocomial myiasis occurrence (Figure 1).

In Bilongué, four collection sites were selected after permission from local residents: the neighbourhood of a garbage bin positioned not far from the "German bridge", the surroundings of Bamena Cultural Center, Bansoa Cultural Center and the garden of the Catholic Church. At Ndakat market located in Ndokoti locality, we were authorized to carry out our collections only at a single site not far from the pig slaughterhouse. At Ndogbong university campus, we deployed our traps at four sampling sites (near the handball stadium, behind "George Ngango" amphitheater, behind the buildings of the Higher Normal School of Technical Education (ENSET) and behind the cafeteria of the Faculty of Sciences. In Souboum, four collection sites were randomly selected in the green space of the health center.

The climate in Douala is tropical [66], characterized by rainfall most months, with a short dry season (mid-November to mid-March of the following year) and a long rainy season (mid-March to mid-November). The average annual rainfall is 3,174 mm in October and the hottest month is February is (26.9°C). The range of monthly rainfall variation is high (5.6 mm in January to 383.3 mm in October) and the average annual precipitation reaches 3,702 mm. A roughly constant annual temperature (average: 25.7°C) and a high level of air humidity (71% in January to 82% in July and August) are reported. A variation of 2.5°C is recorded, the average being 24.4°C in August (coldest month of the year) [67]. December is the driest month (39 mm of rains). Precipitation reaches the peak in August (average: 681 mm) [67]. Between the driest and the wettest of the months, the amplitude of precipitation is 295 mm. October is the month with the highest relative humidity (89.6%) while January presents the lowest relative humidity (84.2%).

2.2. Sample Design

At each sampling site, flies were caught every hour from 6 a.m. to 6 p.m. using traps reinforced with fresh meat as bait. The trapping device consisted of a compact traps made of white cloth in a conical shape (50x50 cm square trap; depth: 20 cm), two forked sticks of 2.5 m each planted vertically on the ground (2 m apart from each other), a stick (2.5 m long) placed transversely above the forks of the vertical sticks and a plywood (50x50 cm) placed on the ground in the middle of the 2 vertical sticks. A 7 m rope tied at one end to the top of the conical trap passed over the transverse stick and the other end was tied to a fixed support 5 m from the device. The rope allowed the conical trap to be suspended 0.5 m from the ground above the plywood and to allow remote release at will. The baits (200 g of fresh muscle and guts pieces collected from butchers) were placed in the center of the plywood. For each session of the day, after 45 min. of waiting, the conical

trap was released by detaching the rope from the support. The trap landed and covered the flies on the bait. Through an opening provided at the top of the trap, we sprayed into the trap an aerosol pyretrinoid synergist insecticide [750 ml spray can of Permethrin (0.25%), Tetramethrin (0.25%), d-Fenotrin (0.01%) and Piperonyl Butoxide (0.34%)], knocking out the flies in captivity. After five minutes, captured flies were picked up using soft forceps and stored in labeled tubes containing 70° alcohol. The plywood was cleaned with 70° alcohol to eliminate odors left behind. Baits were renewed and the conical traps replaced for the next session. In Ndogbong and Souboum where four traps were simultaneously installed, each hour captures were pooled in a same labeled tube. To evaluate the relationship between the daily occurrence of flies and the environmental conditions, air temperature and relative humidity were recorded each hour using a thermo-hygrometer suspended one meter above the ground surface.

2.3. Identification of Fly Specimens

Collected flies were first identified to the family, subfamily and genus levels using appropriate keys [68-70] and then identified to the species level by referring to descriptions and figures available. We used keys for Calliphoridae [71-81], Fanniidae [82], Muscidae [79] and Sarcophagidae [83]. Identifications were confirmed by referring to illustrated catalog and check lists [81, 84-87]. In order to consider recent developments in the taxonomy of identified species and their native range, we consulted old and recent reports available [28, 79, 84, 85, 87-103].

2.4. Statistical Analysis

Data were stored in a digital database format using Excel version 2003 spreadsheet. A species data matrix (abundance or presence/absence of the recorded species) and an environmental data matrix were constructed for each study locality.

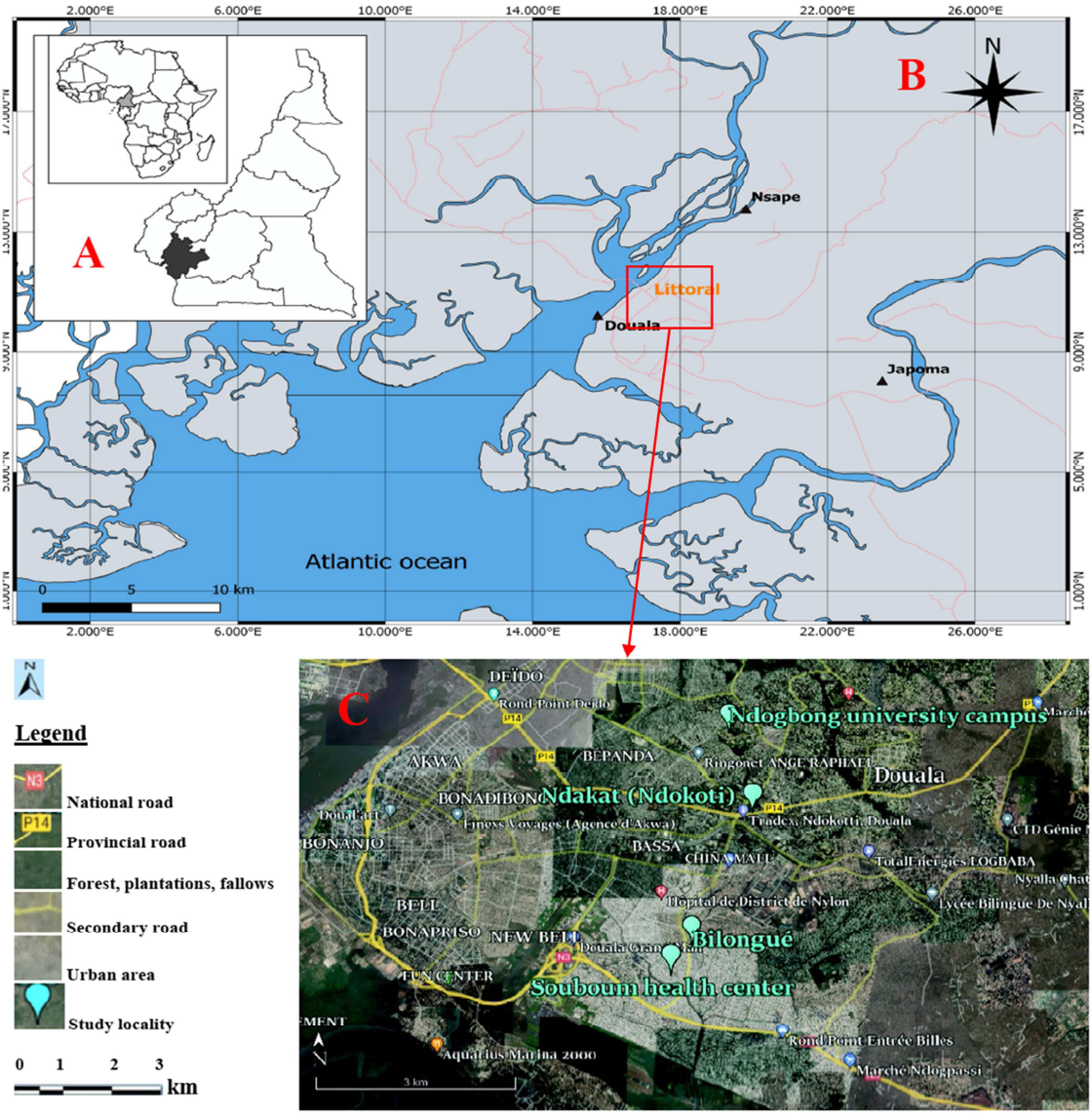

Figure 1. *Location of the study localities in urban areas of Douala (Littoral-Cameroon). A = location of the Littoral region in Cameroon; B = map of the littoral region of Cameroon; C = Location of the study quarters in the Douala city. The maps A and B were adapted from previous reports [104, 105].*

Descriptors (species names or variables) were entered in columns and objects (sampling site code and the collection code) were entered in line. Descriptive analysis of qualitative variables was given in terms of absolute or relative frequencies of occurrences while that of quantitative variables (abundance counts) was given in terms of mean ± standard error (se). Two independents percentages were compared using the Fisher exact test while two mean values were compared using the Student t-test when the conditions of normality and equality variance passed. Otherwise we used the nonparametric Mann-Whitney rang sum test. Simultaneous comparison of several abundance series was set up using Kruskal-Wallis non-parametric test from SigmaStat software 2.0® and pairwise comparisons were set up when relevant using Dunn's procedure because when considering the number of fly species as a metric/response variable, sample units being different, uneven variability could occur between sampling localities.

The simultaneous comparison of several percentages was set up using the independent Pearson's chi-square exact test or the Fisher-Freeman-Halton exact-test from StatXact software 3.1, which are best procedures recommended for nonparametric analysis of unordered contingency tables (our situation). When the difference was significant, the pairwise comparison was conducted. Regression equation was set up when necessary and tested using ANOVA procedure and the coefficient of determination was calculated. Statistical analyses were carried out using StatXact software version 3.1 and SigmaStat for MicroSoft Windows version 2.03 (SPSS, Inc., Chicago, IL). Analysis of the species abundance matrix data allowed the determination of 15 indexes using PAST 3.05 software [106]: (1) absolute abundance of the i^{th} species n_i, (2) sample size n (sum of all absolute abundances), (3) relative abundance of the i^{th} species $p_i = n_i/n$, (4) species richness S (Hill's zero-order diversity number N_0), (5) the maximum abundance n_{max}, (6) Margalef's index $Mg = (S-1)/\ln(n)$ with $0 \leq Mg \leq +\infty$, (7) richness ratio $d = S/n$ with $0 \leq d \leq +1$ knowing that Mg and d indexes are close to zero for low-rich communities while high values of Mg and d suggest very species-rich communities [107, 108], (8) Shannon-Weaver's index H' with $0 \leq H' \leq H'_{max}$, (9) maximum Shannon-Weaver's index $H'_{max} = \ln(S)$ knowing that H' = 0 for a single-species community while $H' = H'_{max}$ when all species S are represented by the same number of individuals (i.e. perfect specific regularity of abundances), (10) Simpson's index D with $0 \leq D \leq +1$ (D close to one suggests that two individuals taken at random belong to the same species for low diversity and D close to zero for communities of high diversities), (11) Hill's first-order diversity number $N_1 = e^{H'}$ with $1 \leq N_1 \leq N_0$ (estimated number of simply abundant species), (12) Hill's second-order diversity number $N_2 = 1/D$ (estimated number of co-dominant species) with $1 \leq N_2 \leq N_1$ [109], (13) Hill diversity ratio $Hill = N_2/N_1$ with $0 \leq Hill \leq +1$ (Hill's evenness index), (14) Pielou's evenness index $J = H'/\ln(S)$, and (15) Berger-parker dominance index $I_{BP} = n_{max}/n$ which expresses the importance of the most dominant species (low value reflects a high species diversity). The Piélou's index varies from zero (complete heterogeneity or absence of regularity) to one (complete regularity or perfect homogeneity of the community) [110-112]. Comparison of the species richness was performed using the individual rarefaction procedure [113]. The non parametric estimation Chao1 was used to estimate the theoretical species richness T [114] and the sampling effort was estimated as (S/T)x100. The overall species covariance was evaluated using Schluter's procedure [108, 111]. Between species correlation was evaluated using Kendall's *tau* (τ) coefficient. The dissimilarity between the study localities was evaluated using Bray-Cutis index [115]. The rank abundance plotting was used to illustrate the shape of the species abundance distribution (SAD). For the present study, we used six commonly used theoretical SAD models to fit our curves [116-124]: Fisher's log-series model (LS), MacArthur's Broken-Stick model (BS), Log-linear (LL) or Geometric model (GM), Lognormal model (LN), Zipf model (Z) and Zipf-Mandelbroot model (ZM). The best fitted model was selected using AIC procedure [125, 126]. The package vegan of R 3.4.1 software [127] helped us to adjust the SADs. Parameters of the best fitted theoretical models were determined. The maximum abundance n_1 of the first-rang species, the Motomura's environment constant m (decay rate of abundance per rank) and the Preston's environmental constant m' were determined for GM and LN models respectively.

2.5. Abbreviations

%:	percentage
A. ornata:	*Anthomyia ornata* (Bigot 1885)
a.s.l:	above sea level
AIC:	Akaïke Information Criteria
BC:	Bray-Curtis dissimilarity index
BIC:	Bayesian Information Criteria
Ca. vicina:	*Calliphora vicina* Robineau-Desvoidy 1830
Ca. vomitoria:	*Calliphora vomitoria* (Linnaeus 1758)
Ch. bezziana:	*Chrysomya bezziana* (Villeneuve 1914)
Ch. megacephala:	*Chrysomya megacephala* (Fabricius 1794)
Ch. putoria:	*Chrysomya putoria* (Wiedemann 1830)
Ch. rufifacies:	*Chrysomya rufifacies* (Macquart 1842)

Co. anthropophaga:	*Cordylobia anthropophaga* (Blanchard & Berenger-Feraud 1872)
Co. rodhaini:	*Cordylobia rodhaini* Gedoelst 1910
Chao1:	Chao's Abundance based non-parametric estimators of the species richness
cm:	centimeter
d:	Richness ratio
D:	Simpson's index
df:	degree of freedom
E. histolytica:	*Entamoeba histolytica*
$E(S_n)$:	expected species richness for a theoretical sample of n individuals
F. canicularis:	*Fannia canicularis* (Linnaeus 1761)
F. ornata:	*Fannia ornata* (Meigen 1826)
g:	gram
GM:	Geometric series theoretical model
I_{BP}:	Berger-parker dominance index
J:	Pielou's evenness index
H. lineatum:	*Hypoderma lineatum* (Villers 1789)
H':	Shannon-Weaver diversity index
L. ampullaceal:	*Lucilia ampullaceal* Villeneuve 1922
L. caesar:	*Lucilia caesar* (Linnaeus 1758)
L. bufonivora:	*Lucilia bufonivora* Moniez 1876
L. cuprina:	*Lucilia cuprina* (Wiedemann 1830)
L. elongata:	*Lucilia elongata* Shannon 1924
L. eximia:	*Lucilia eximia* (Wiedemann 1819)
L. illustris:	*Lucilia illustris* Meigen 1826
L. sericata:	*Lucilia sericata* (Meigen 1826)
L. silvarum:	Lucilia silvarum (Meigen)
LL:	Motomura's log-linear model
m:	meter
LN:	Preston's lognormal model
LS:	Fisher's log-series model
m':	Preston's environmental constant
mc:	Motomura's environmental constant
Mg:	Margalef richness index
ml:	milliliter
Mu. autumnalis:	*Musca autumnalis* De Geer 1776
Mu. conducens:	*Musca conducens* Walker 1859
Mu. crassirostris:	*Musca crassirostris* Stein 1903
Mu. (Musca) domestica:	*Musca (Musca) domestica* Linnaeus 1758
Mu. sorbens:	*Musca sorbens* Wiedemann 1830
Ms. levida:	*Muscina levida* (Harris 1780)
Ms. assimilis:	*Muscina assimilis* (Fallén 1823)
Ms. pabulorum:	*Muscina pabulorum* (Fallén 1817)
Ms. prolapsa:	*Muscina prolapsa* (Harris 1780)
n:	sample seize or the sum of absolute abundances of all recorded species
n_i:	absolute abundance of i^{th} species
N_0:	Hill's zero-order diversity number also called species richness S
N_1:	Hill's first-order diversity number
N_2:	Hill's second-order diversity number
p:	statistical probability value
P. regina:	*Phormia regina* (Meigen 1826)
Po. regina:	*Phormia regina* (Meigen 1826)
S:	species richness (total number of species)
Sa. (Bercaea) africa:	*Sarcophaga (Bercaea) africa* Wiedemann 1824
Sa. carnaria:	*Sarcophaga carnaria* (Linnaeus 1758)
SAD:	Species Abundance Distribution
SE:	sampling effort
spp.:	*species plurimae*

St. calcitrans:	*Stomoxys calcitrans* (Linnaeus 1758)
St. niger bilineatus:	*Stomoxys niger bilineatus* Grünberg 1906
St. omega:	*Stomoxys omega* Newstead Dutton & Todd 1907
St. xanthomelas:	*Stomoxys xanthomelas* Roubaud 1937
r:	Pearson's correlation coefficient
r^2:	linear regression's coefficient of determination
se:	standard error
τ:	Kendall's tau correlation
T:	Theoretical species richness determined using Chao1 index
T*:	lognormal theoretical number of species avaible for observation
VR:	Schluter's Variance ratio
χ^2:	chi-square statistic
Z:	Zipf's model
ZM:	Zipf-Mandelbrot's model.

3. Results

3.1. Species Richness and Diversity of Flies

Collected flies (order Diptera Linnaeus, 1758; suborder Brachycera Macquart, 1834), belonged to four families [Calliphoridae Brauer & Bergenstamm, 1889; Fanniidae Schnabl & Dziedzicki, 1911; Muscidae Latreille, 1802 and Sarcophagidae Haliday, 1853], five subfamilies [Calliphorinae Brauer and Bergenstamm, 1889, Chrysomyiinae Malloch, 1927, Fanniinae Malloch 1917, Muscinae Latreille, 1802 and Sarcophaginae Macquart, 1835], seven genera [Chrysomya Robineau-Desvoidy, 1830, Fannia Robineau-Desvoidy, 1830 (=Anthomyia Meigen, 1803), Lucilia Robineau-Desvoidy, 1830, Musca Linnaeus, 1758, Muscina Robineau-Desvoidy, 1830, Phormia Robineau-Desvoidy, 1830 and Sarcophaga Meigen, 1826] and 14 species (Table 1). The flies collected came mostly from Souboum locality (39.5%), followed by those from Ndogbong (31.8%), Bilongué (23.6%) and rarely from Ndakat (5.1%). Three species were collected only in Ndogbong locality, divided into two Calliphorinae [*Lucilia elongata* Shannon, 1924 and *L. eximia* Wiedemann, 1819] and one Faniinae [*Fannia ornata* Meigen, 1826 (=*Anthomyia ornata* Bigot, 1885]. The Muscinae *Musca autumnalis* De Geer, 1776 was recorded in two localities (Ndogbong and Souboum). The Chrysomiinae *Chrysomya megacephala* (Fabricius, 1794) was recorded in three localities (Bilongué, Ndogbong and Souboum Health Center). The Calliphorinae *L. illustris* Meigen, 1826 was recorded in three localities (Bilongué, Ndakat market and Ndongbong University Campus). The Muscinae *Muscina levida* (Harris, 1780) [=*Ms. assimilis* Fallén, 1823] was recorded in three localities (Ndakat market, Ndogbong University Campus and Souboum Health Center). Seven species occurred in the four study localities, and were divided into three Chrysomyiinae [*Chrysomya putoria* (Wiedemann, 1830), *Ch. rufifacies* (Macquart, 1842) and *Phormia regina* (Meigen, 1826)], one Calliphorinae (*Lucilia* spp. Robineau-Desvoidy, 1830), two Muscinae [*Mu. (Musca) domestica* Linnaeus, 1758 and *Ms. pabulorum* (Fallén, 1817) (=*Muscina prolapsa* (Harris, 1780)] and one Sarcophaginae (*Sarcophaga (Bercaea) africa* Wiedemann, 1824) (Table 1). All identified species are known as public and/or livestock health pests. *L. elongata* is known as an obligate myiasigenic fly in anurans. Thirteen synanthropic species (92.9%) were divided into nine accidental human myiasigenic species (64.3%) and four species of veterinary importance (28.6%). Accidental human myiasigenic flies were *Ch. megacephala* (Chrysomiinae), *Ch. putoria, Ch. rufifacies, F. ornata (=A. ornata), Lucilia* spp., *L. eximia, L. illustris, Ms. pabulorum (= Ms. Prolapsa)* and *P. regina* (Table 1) while veterinary important flies were *Mu. autumnalis, Mu. (Musca) domestica (Muscinae), Ms. levida (=Ms. assimilis)* and *Sa. africa*. Seven species are important in public and veterinary health because they disseminate many pathogens by phoresy [*Ch. megacephala, Ch. rufifacies, F. ornata (=A. ornata), Lucilia* spp., *L. eximia, L. illustris* (Calliphorinae) and *Po. regina*]. Thirteen species of flies (92.9%) are known as phoresical vectors of agents responsible for parasitic diseases in humans and livestock. These species are *Ch. megacephala, Ch. putoria, Ch. rufifacies, F. ornata (=A. ornata), Mu. autumnalis, Mu. (Musca) domestica, Ms. levida (=Ms. assimilis), Ms. pabulorum (=Ms. prolapsa), Lucilia* spp., *L. eximia, L. illustris, Po. regina* and *Sa. (Bercaea) africa* (Table 1). Ten species are of phorensic importance: *C. megacephala, Ch. putoria, Ch. rufifacies (Chrysomiinae), F. ornata [=A. ornata], Lucilia* spp., *L. illustris, Ms. levida (=Ms. assimilis), Ms. pabulorum (=Ms. prolapsa), Po. regina,* and *Sa. (Bercaea) africa*. Identified species are worldwide distributed. Three species (21.4%) (*Ch. putoria, F. ornata (=A. ornata*) and *Sa. (Bercaea) africa*] are of Afrotropical origin while 12 exotic species (85.7%) are divided into two species (14.3%) of Australasian origin (*Ch. megacephala* and *Ch. rufifacies*), five species of Nearctic origin [*Lucilia* spp., *L. elongata, L. illustris, Ms. pabulorum (=Ms. Prolapsa)* and *Po. regina*], one species (7.1%) of Neotropical origin (*L. eximia*) and three species of Palearctic origin [*Mu. autumnalis, Mu. (Musca) domestica* and *Ms. levida (=Ms. assimilis)*] (Table 1). All collected specimens belonged to the facultative myiasigenic fly species.

Table 1. *Absolute and relative abundance and pest status of the collected flies.*

Familly / Subfamilly	Species name	Status	References	Localities (%)				Global (%)
				I	II	III	IV	
Calliphoridae								
Calliphorinae	*Lucilia elongata* Shannon, 1924	P, S, A, NE	[72, 76, 129]	-	-	30 (0.41)	-	30 (0.41)
	L. eximia (Wiedemann, 1819)	P, S, *, #, §, NT	[72]	-	-	16 (0.22)	-	16 (0.22)
	L. illustris Meigen, 1826	P, S, *, #, §, F, W	[73]	9 (0.12)	3 (0.04)	23 (0.31)	-	35 (0.47)
	Lucilia spp. Robineau-Desvoidy, 1830	P, S, *, #, §, F, W	[74, 76, 77]	430 (5.83)	36 (0.49)	363 (4.92)	516 (6.99)	1345 (18.23)
Chrysomyiinae	*Chrysomya megacephala* (Fabricius, 1794)	P, S, *, #, §, F, W (AU)	[28, 71, 73-75, 78, 81, 84, 89, 90-92, 98]	2 (0.03)	-	41 (0.56)	1 (0.01)	44 (0.60)
	Ch. putoria (Wiedemann, 1830)	P, S, *, #, §, F, TA	[71, 73-75, 81, 88, 89, 94]	678 (9.19)	58 (0.79)	418 (5.66)	1563 (21.18)	2717 (36.82)
	Ch. rufifacies (Macquart, 1842)	P, S, *, #, §, F, AU	[73, 74, 128],	346 (4.69)	156 (2.11)	663 (8.98)	404 (5.47)	1569 (21.26)
	Phormia regina (Meigen, 1826)	P, S, *, #, §, F, W (HO)	[72-74, 78, 130]	144 (1.95)	45 (0.61)	210 (2.85)	207 (2.81)	606 (8.21)
Fanniidae								
Fanniinae	*Fannia ornata* (Meigen, 1826) =*Anthomyia ornata* (Bigot, 1885)	P, S, *, #, §, F, TA	[82, 85]	-	-	8 (0.11)	-	8 (0.11)
MUSCIDAE								
Muscinae	*Musca autumnalis* De Geer, 1776	P, S, V, §, W (PA)	[79, 80, 102]	-	-	133 (1.80)	2 (0.03)	135 (1.83)
	Mu. (Musca) domestica Linnaeus, 1758	P, S, V, §, W (PA)	[79, 80, 97, 100, 101]	93 (1.26)	36 (0.49)	258 (3.50)	170 (2.30)	557 (7.55)
	Muscina levida (Harris, 1780) =*Ms. assimilis* (Fallén, 1823)	P, S, V, §, F, W (PA)	[79, 80, 103]	-	6 (0.08)	20 (0.27)	21 (0.28)	47 (0.64)
	Ms. pabulorum (Fallén, 1817) = *Muscina prolapsa* (Harris, 1780)	P, S, *, §, F, PA	[79, 80, 87, 95, 96]	24 (0.33)	24 (0.33)	141 (1.91)	31 (0.42)	220 (2.98)
Sarcophagidae								
Sarcophaginae	*Sarcophaga (Bercaea) africa* Wiedemann, 1824	P, S, V, §, F, W (TA)	[28, 83, 93, 99]	12 (0.16)	12 (0.16)	25 (0.34)	1 (0.01)	50 (0.68)
	Total			1738 (23.55)	376 (5.10)	2349 (31.83)	2916 (39.52)	7379 (100.00)

I: Bilongué; II: Ndakat; III: Ndogbong; IV: Souboum; *: accidental myiasigenic species in man; §: Human disease vector; #: Species of medical importance; A: obligate anuran myiasis; AU: Australasian origin; F: species of forensic importance; HO: holarctic distributed species; NE: nearctic origin; NT: neotropical origin; P: pest species; PA: Palaearctic origin; S: synantropic species; TA: Tropical Africa origin; V: species of veterinary importance; W: worldwide distribution.

3.2. Species Abundance

A total of 7,379 specimens were collected (8 specimens of *F. ornata* to 2,717 specimens of *Ch. putoria*; mean ± se: 527 ± 216 specimens, 14 species) divided into 1,738 specimens (23.6%) in Bilongué (2 to 678 specimens; 193 ± 80 specimens, 9 species), 376 specimen (5.1%) in Ndakat (3 to 156 specimens; 42 ± 16 specimens, 9 species), 2,349 specimens (31.8%) in Ndogbong (8 to 663 specimens; 168 ± 53 specimens, 14 species) and 2916 specimens (39.5%) in Souboum (1 to 1563 specimens; 292 ± 153 specimens, 10 species). At each locality and between the different localities, overall the variation in the percentages of occurrence of flies was significant (global test using Pearson's asymptotic chi-square: χ^2 = 1,555.7, df = 39, p = 0; pairwise comparisons: Bilongué *vs.* Ndakat: χ^2 = 235.69, df = 9, p = 0: Bilongué *vs.* Ndogbong: χ^2 = 512.95, df = 13, p = 0; Bilongué *vs.* Souboum: χ^2 = 149.60, df = 10, p = 0; Ndakat *vs.* Ndogbong: χ^2 = 80.81, df = 13, p = 0; Ndakat *vs.* Souboum: χ^2 = 80.81, df = 13, p = 0; Ndogbong *vs.* Souboum: χ^2 = 446.22, df = 10, p = 0). *Ch. putoria* was the most collected fly (36.8%) followed by *Ch. rufifacies* (21.3%), *Lucilia* spp. (18.2%), *Po. regina* (8.2%), *Mu. (Musca) domestica* (7.5%), *Ms. pabulorum* (=*Ms. Prolapsa*) (3.0%) and *Mu. autumnalis* (1.8%). Seven species were rarely collected, the percentage being in each case less than 1.0% [0.6% for *Ch. megacephala*, 0.4% for *L. elongata*, 0.2% for *L. eximia*, 0.5% for *L. illustris*, 0.1% for *Po. regina*, 0.6% for *Ms. levida* (= *Ms. assimilis*) and 0.7% for *Sa. (Bercaea) africa*] (Table 1).

3.3. Community Structure

The species richness and the species diversity were statistically low because the richness ratio was close to zero (14 species, Margalef index: Mg = 1.460, Shannon-Weaver index: H' = 1.751, Maximum value of the Shannon-Weaver index: H'_{max} = 2.640, richness ratio; d = 0.002). A similar observation was recorded in each of the four localities of the study [Bilongué: 9 species (64.3% of the total collected species), Mg = 1.072, H' = 1.526, H'_{max} = 2.197, d = 0.005; Ndakat: 9 species (64.3%), Mg = 1.349, H' = 1.747, H'_{max} =

2.197, d = 0.024; Ndogbong: 14 species (100.0%), Mg = 1.675, H' = 2.057, H'_{max} = 2.639, d = 0.006; Souboum: 10 species (71.4%), Mg = 1.128, H' = 1.362, H'_{max} = 2.303, d = 0.003] (Table 2). Pairwise comparisons of Shannon-Weaver indexes showed in each case, a significant difference. The same was true for Simpson indexes except between Bilongué and Ndakat (Table 2). Based on the Chao1 nonparametric estimator of the 'TRUE" species richness, the sampling success was very high (100.0%) with the exception of Souboum locality where a low score (90.9%) was recorded and where one species had not been collected (Table 2). Differences in the Shannon-Weaver indexes were significant between all localities. It was the same for Simpson indexes except between Bilongué and Ndakat (Table 2).

We noted a high even assemblage of flies (Hill ratio and Piélou's indexes closed to one) except in Souboum locality where Pielou's index was close to the median value (Table 2). All the assemblages were moderately dominated by a few species because values of the Berger-Parker index were closed to the median value, except in the locality of Ndogbong where it was quite low.

The individual rarefaction analysis made it possible to note that for a standard sample of 361 specimens, flies appeared most diverse in Ndogbong locality [$E(S_{n=361})$ = 14 ± 1 species], followed by those from Ndakat [$E(S_{n=361})$ = 9 ± 0 species], from Bilongué [$E(S_{n=361})$ = 8 ± 1 species] and flies from Souboum locality appeared less diverse [$E(S_{n=361})$ = 7 ± 1 species]. The rank-abundance plotting of the pooled data presented a concave appearance significantly typical of Fisher's log-series model, suggesting the presence of co-dominant species within the assemblage of flies (Figure 2). The same shape of the graphs was observed in each locality (Figure 3).

Based on the Hill's N_1 index, within the global assemblage, six species (42.9%) were simply abundant (*F. ornata*, *Lucilia* spp., *Mu. autumnalis*, *Ms. pabulorum (=Ms. prolapsa), P. regina* and *Sa. (Bercaea) africa*) and therefore eight species (57.1%) were rare. At Bilongué five species (35.7%) were simply abundant (*Ch. putoria*, *Ch. rufifacies*, *Lucilia* spp., *Mu. (Musca) domestica* and *Po. regina*) and therefore nine species (64.3%) were rare. In Ndakat, six species (42.9%) were simply abundant (*Ch. putoria*, *Ch. rufifacies*, *Lucilia* spp., *Mu. (Musca) domestica, Ms. pabulorum* and *Po. regina*) and eight species (57.1%) were rare. In Ndogbong, eight species (57.1%) were simply abundant (*Ch. megacephala, Ch. putoria*, *Ch. rufifacies*, *Lucilia* spp., *Mu. autumnalis*, *Mu. (Musca) domestica*, *Ms. pabulorum* and *P. regina*) and six species (42.9%) were rare.

Table 2. *Matrix of the species richness, diversity, evenness and dominance indices.*

Indexes	Localities				Total
	I	II	III	IV	
n	1,738	376	2,349	2,916	7,379
S	9	9	14	10	14
n_{max}	678	156	663	1,563	2,717
Mg	1.072	1.349	1.675	1.128	1.460
Ratio: d	0.005	0.024	0.006	0.003	0.002
Chao 1	9	9	14	11	14
SE (%)	100.0	100.0	100.0	90.9	100.0
H'	1.526	1.747	2.057	1.362	1.751
H'_{max}	2.197	2.197	2.639	2.303	2.640
D	0.263	0.234	0.163	0.346	0.228
Hill's N_1	5	6	8	4	6
Hill's N_2	4	4	6	3	4
N_2/N_1	0.827	0.745	0.785	0.739	0.762
Pielou: J	0.694	0.795	0.779	0.592	0.663
I_{BP}	0.390	0.415	0.282	0.536	0.368
t-test pairwise comparison of species diversity indexes: p-value					
	Shannon index H'		Simpson index D		
I *vs.* II	$p = 5.2x10^{-6}$ *		p = 0.089 ns		
I *vs.* III	$p = 6.8x10^{-90}$ *		$p = 2.7x10^{-48}$ *		
I *vs.* IV	$p = 1.7x10^{-10}$ *		$p = 3.0x10^{-18}$ *		
II *vs.* III	$p = 1.8x10^{-10}$ *		$p = 2.0x10^{-5}$ *		
II *vs.* IV	$p = 4.1x10^{-15}$ *		$p = 5.5x10^{-10}$ *		
III *vs.* IV	$p = 6.4x10^{-163}$ *		$p = 1.6x10^{-98}$ *		

I to IV see Table 1; * = significant difference, n = sample size; n_{max} = maximum abundance; S = observed species richness; Mg = Margalef's richness index; D = Simpson's diversity index; d = richness ratio; H' = Shannon-Weaver's diversity index; H_{max} = Shannon-Weaver's maximum diversity index; J = Pielou's evenness index; SE = sampling effort; N_1 = Hill's diversity number one = $e^{H'}$; N_2 = Hill's diversity number two; Hill = Hill's diversity ratio; I_{BP} = Berger-Parker's dominance index.

Finally in Souboum, four species (28.6%) were simply abundant (*Ch. putoria*, *Ch. rufifacies, Lucilia* spp. and *Po. regina*) and ten species (71.4%) were rare (Table 2). Based on the Hill's N_2 index, four species (28.6%) [*F. ornata*, *Lucilia* spp., *Po. regina*, and *Sa. (Bercaea) africa*] co-dominated the overall assemblage (Table 2 and Figure 2). Assemblages of flies from Bilongué and Ndakat were co-dominated by four species (*Ch. putoria*, *Ch. rufifacies*,

Lucilia spp. and *Po. regina*) (Table 2, Figure 3A and 3B). The aseemblage of flies from Ndongbong was co-dominated by six species [*Ch. putoria*, *Ch. rufifacies*, *Lucilia* spp., *Mu. (Musca) domestica*, *Ms. pabulorum* and *Po. regina*] (Table 2 and Figure 3C). Finally the assemblage from Souboum was co-dominated by three species (*Ch. putoria*, *Ch. rufifacies* and *Lucilia* spp.) (Table 2 and Figure 3D).

Based on the species composition and the Bray-Curtis index, although a few cosmopolitan species were sampled, a low level of dissimilarity was noted when we compared Ndakat to Bilongué (BC = 0.350), Ndogbong (BC = 0.276) and Souboum (BC = 0.220). A rather high level of dissimilarity was noted when comparing assemblages from three localities (Bilongué *vs.* Ndogbong: BC = 0.690; Bilongué *vs.* Souboum: BC = 0.738; Ndogbong *vs.* Souboum: BC = 0.614).

The cluster analysis maked possible to recognize three groups at a Jaccard similarity index equal to 0.76. The first group consisted of assemblages from Bilongué and Ndakat while Ndogbong and Souboum assemblages represented two separated groups (Figure 4).

Adjustment of the species abundance distributions (SADs) to the five commonly known theoretical models showed that the fit was of approximate quality in Ndakat locality (Pearson correlation: r = -0.967; p = $2.1x10^{-5}$) and of satisfactory quality in other localities (Bilongué: r = -0.985, p = $1.3x10^{-6}$; Ndogbong: r = -0.985, p = $1.7x10^{-10}$; Souboum: r = -0.977, p = $1.2x10^{-6}$) and the same observation was valid for the overall assemblage (r = -0.984, p = $2.1x10^{-10}$).

On the base of AIC values (Table 3) and the SAD plottings (Figures 3), the Motomura's log-linear model (LM) fitted the global assemblage of flies [deviance =, 192.06, maximum abundance: n_1 = 2717, Motomura's environmental constant: mc = 0.646, regression equation: $Log(n_i) = (-0.19 \pm 0.01)i + (3.56 \pm 0.08)$, S = 14 species, coefficient of determination: $r^2 = 0.969$, regression ANOVA: $F_{(1; 12)} = 372.17$, $p<0.001$), GM's model $n_i = n_1(mc)^{(i-1)} \pm$ se: $n_i = [2717(0.646)^{(i-1)} \pm 25]$ where "i" was the rank of the species whith abundances ranked in descending order ($1 \leq i \leq S$)].

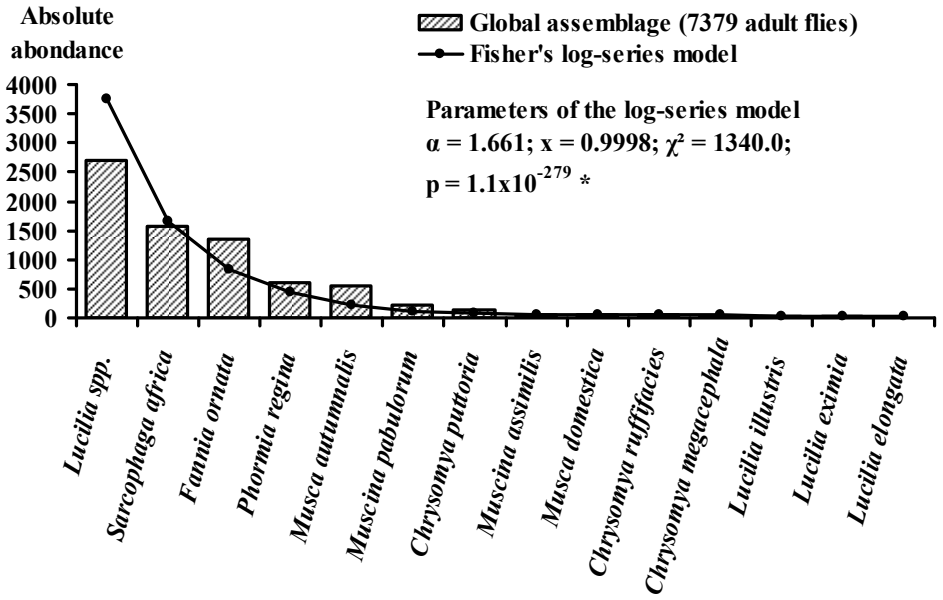

Figure 2. *Rank-frequency diagram of the total collected adult flies showing species in decreasing order of numerical dominance.*

The same observation was noted in the assemblage from Bilongué [deviance = 78.267, n_1 = 678, mc = 0.485, $Log(n_i) = (-0.31 \pm 0.02)i + (3.33 \pm 0.12)$, S = 9 species, $r^2 = 0.971$, $F_{(1; 7)} = 231.601$, $p<0.001$, GM's model: $n_i = [678(0.485)^{(i-1)} \pm 25]$. A similar situation was noted in Ndogbong [deviance = 54.814, n_1 = 663, mc = 0.715, $Log(n_i) = (-0.146 \pm 0.007)i + (2.97 \pm 0.06)$, S = 14 species, $r^2 = 0.970$, $F_{(1; 12)} = 385.50$, $p<0.001$, GM's model: $n_i = [663(0.715)^{(i-1)} \pm 7]$ and Souboum [deviance = 162.67, n_1 = 1563, mc = 0.415, $Log(n_i) = (-0.38 \pm 0.03)i + (3.72 \pm 0.18)$, S = 10 species, $r^2 = 0.954$, $F_{(1; 8)} = 167.32$, $p<0.001$, GM's model ± se: $n_i = [1563(0.415)^{(i-1)} \pm 25]$.

The assemblage from Ndakat market fitted the Preston's log-normal model (LN) [deviance = 12.484, 376 specimens, nine species, lognormal mean: 1.381, lognormal variance: 0.279, Preston's environmental constant: m' = 3.587, LN's parameter: a = 0.294, number of species in the modal octave: S_0 = 4, lognormal theoretical number of species available for observation: T* = 24 which suggests that in this locality, 15 species were not collected during our capture sessions, sampling effort for LN species distribution: 37.5%, LN's model ± se: $S(R) = [4e^{[-(0.294)^2R^2)} \pm 1]$ with S(R) being the number of species in the R^{th} octave].

3.4. Daily Occurrence of Flies

During 16 days (four days per localities and 13 sessions per day from 6 a.m. to 6 p.m.), the air temperature recorded varied from 25.2 to 51.5°C (mean ± se: 29.5 ± 0.2°C, 208 records). The air humidity ranged from 33.0 to 72.0% (61.6 ± 0.4%, 208 records).

During the day, a significant positive correlation was noted between the air temperature and the rhythm of activity of *F. ornata, L. illustris* and *Mu. domestica*. As for air humidity, the significant negative correlation was noted for *Ch. puttoria.* The other correlations were not significant (Table 4).

Ch. megacephala was recorded only in two localities (rarely in Bilongué and simply abundant in Ndogbong). It was collected at 8 a.m., 10 a.m., intensely between 12 p.m. and 2 p.m. and weakly at 4 p.m. (Figure 5A).

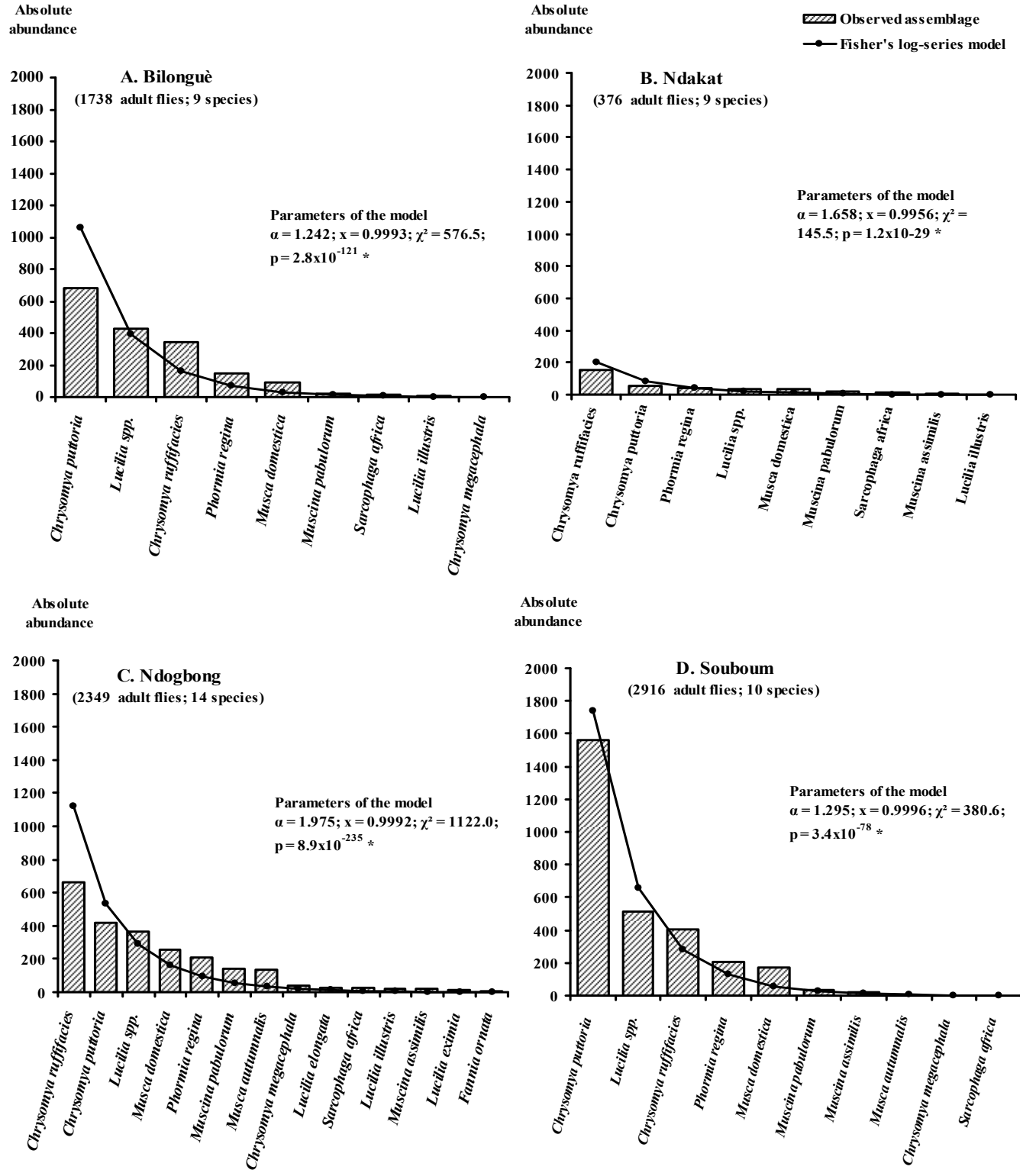

Figure 3. *Rank-frequency diagrams of absolute abundances of flies collected from four localities. For each locality, percentages were calculated on the total number of individuals collected.*

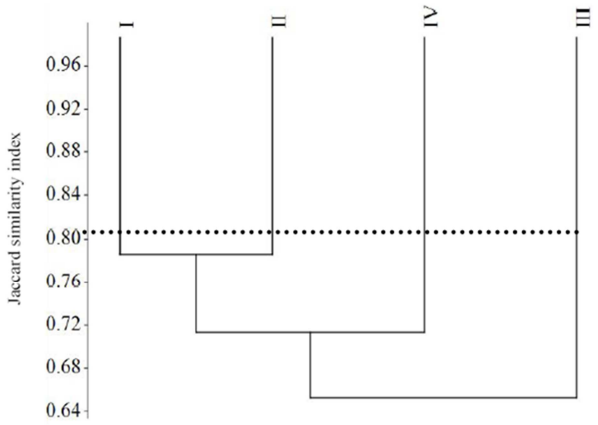

Figure 4. *Hierarchical Cluster Analysis based on Jaccard index using the "Unweighted Pair Group Method with Arithmetic mean" algorithm (UPGMA) and showing similarity in assemblages of flies among four sampling localities (Cophenetic correlation: 0.899). I = Bilongué; II = Ndakat; III = Ndogbong; IV = Souboum.*

Ch. putoria was dominant in Bilongué, Ndogbong and Souboum, and was recorded at all hours of the day with three occurrence peaks at 10 a.m., 1 p.m. and 5 p.m. (Figure 5B). *Ch. rufifacies* was a dominant species recorded in Bilongué, Ndakat, Ndogbong and Souboum, at all hours of the day with an occurrence peak between 1 p.m. and 3 p.m. (Figure 5C). *F. ornata* was rarely collected only in Ndogbong between 11 a.m. and 1 p.m. (Figure 5D). *Lucilia* spp. was also a dominant species recorded in the four localities, at all hours of the day with two occurrence peaks at 9 a.m. and 1 p.m. (Figure 5E). *L. elongata* was found in Ndogbong, more intensely at 8 a.m. and rarely at 12 p.m. and 4 p.m. (Figure 5F). *L. eximia* was found in Ndogbong, more intensely at 1 p.m. and rarely at 9 a.m. and 2 p.m. (Figure 5G).

L. illustris was also a rare species found in Bilongué, Ndakat and Ndogbong, more intensely at 10 a.m. and rarely at 7 a.m., 9 a.m., 11 a.m., 2 p.m. and 4 p.m. (Figure 5H). *Mu. autumnalis* was found in Ndogbong between 2 p.m. and 5 p.m. (Figure 5I). *Mu. (Musca) domestica* was recorded in three localities (Bilongué, Ndakat and Ndogbong) where it was collected at every hour of the day with peaks of occurrence at 8 a.m., 11 a.m. and 2 p.m. (Figure 5J). *Ms. levida (=Ms. assimilis)* was a rare species found in three localities (Ndakat, Ndogbong and Souboum) at 7 a.m., 10 a.m. to 12 p.m., at 2 p.m. and 5 p.m. (Figure 5K). *Ms. pabulorum (=Ms. prolapsa)* found in the four localities (simply abundant in Ndakat, dominant in Ndogbong, rare in Bilongué and Souboum), was collected from 7 a.m. to 6 p.m. with a large occurrence peak between 8 a.m. and 9 a.m. and a weak one between 2 p.m. and 3 p.m. (Figure 5L).

Table 3. *Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) values for the adjusted theoretical models.*

SAD theoretical models	AIC (BIC) values and the best fitted theoretical model				
	Bilongué S = 9, n = 1738	**Ndakat** S = 9; n = 376	**Ndogbong** S = 14; n = 2349	**Souboum** S = 10; n = 2916	**Global** S = 14; n = 7379
Broken-stick (Null)	404.309 (404.309)	68.266 (68.266)	324.857 (324.857)	1303.07 (1303.07)	2667.76 (2667.76)
Log-linear (Pre-emption)	133.419 (133.617) *	73.881 (74.078)	143.096 (143.735) *	220.71 (221.01) *	288.70 (289.34) *
Log-normal (Preston)	245.206 (245.601)	61.783 (62.178) *	258.534 (259.812)	233.54 (234.15)	874.82 (876.10)
Zipf	443.478 (443.873	74.487 (74.882)	474.495 (475.773)	459.44 (460.05)	1571.15 (1572.43)
Zipf-Mandelbrot	NA	74.166 (74.758)	146.835 (148.752)	224.71 (225.61)	292.68 (294.60)

SAD: Species Abundance Distribution, BIC: Bayesian Information Criteria, S: species richness, n = sample size or total number of collected specimens, * the best fitted theoretical model of the SAD, NA: Not available.

Table 4. *Correlation between the flies' rhythm of activity and two climatic conditions recorded during four days in each locality.*

Species	Pearson correlation: 208 essais (p-value)	
	Temerature	**Air humidity**
Chrysomya puttoria	0.104 (0.136) ns	-0.243 ($4.1x10^{-4}$) *
C. megacephala	0.085 (0.222) ns	0.059 (0.400) ns
C. ruffifacies	0.007 (0.919) ns	0.092 (0.185) ns
Fannia ornata	0.191 (0.006) *	-0.071 (0.312) ns
Lucilia spp.	0.028 (0.690) ns	0.004 (0.953) ns
L. elongata	0.077 (0.272) ns	0.010 (0.888) ns
L. eximia	0.102 (0.144) ns	0.010 (0.886) ns
L. illustris	0.157 (0.023) *	-0.022 (0.750) ns
Phormia regina	0.050 (0.470) ns	-0.050 (0.474) ns
Musca automnalis	0.033 (0.638) ns	0.087 (0.214) ns
Mu. domestica	0.161 (0.020) *	-0.012 (0.865) ns
Muscina pabulorum	0.129 (0.062) ns	0.023 (0.740) ns
Ms. assimilis	0.025 (0.723) ns	-0.020 (0.772) ns
Sarcophaga africa	0.088 (0.207) ns	0.043 (0.536) ns

ns: not significant correlation ($p \geq 0.05$), *: significant correlation ($p < 0.05$), Signicant correlations are in bolt.

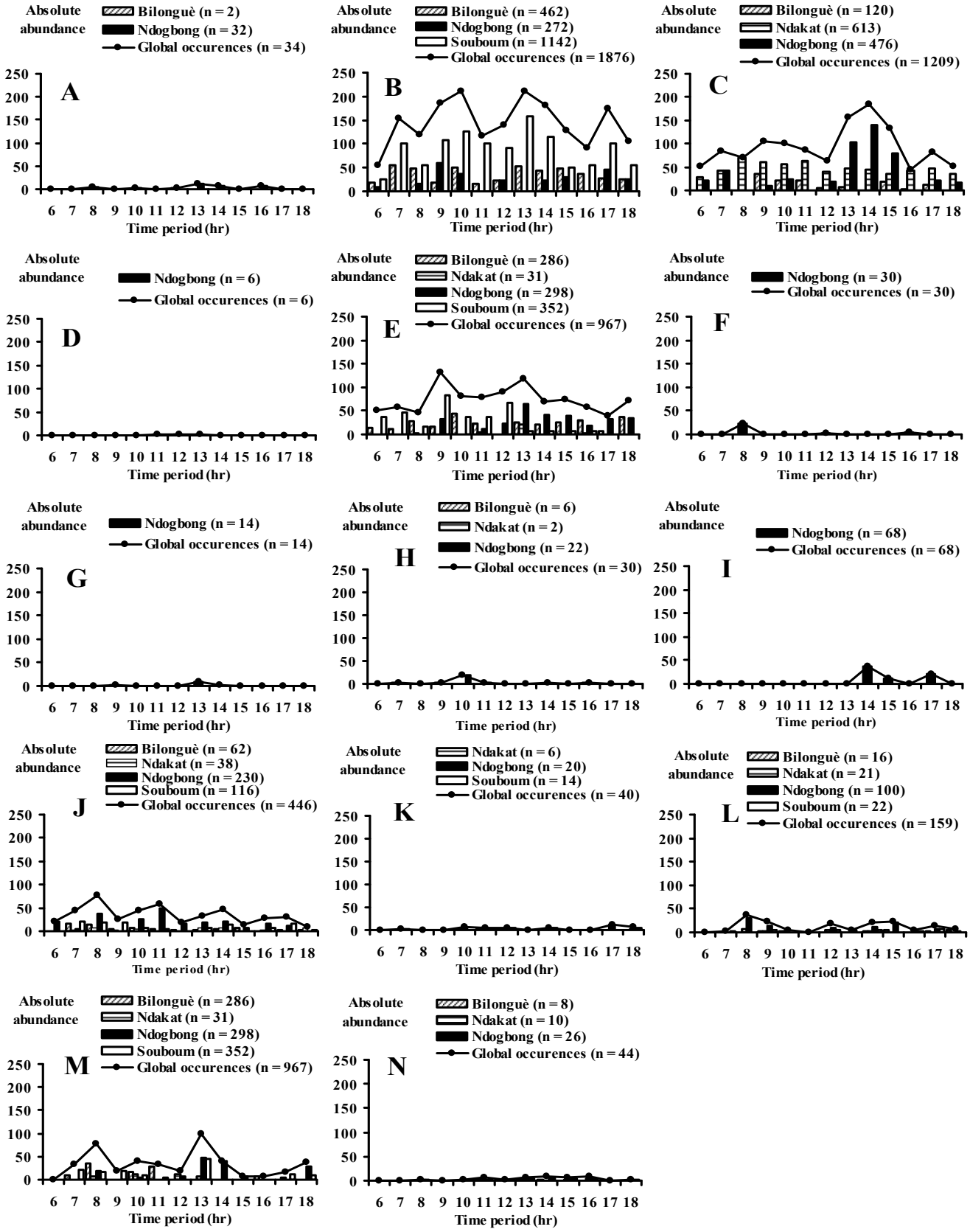

Figure 5. *Rhythm of occurrence during the day of the flies collected. A: Chrysomya megacephala (Fabricius, 1794), B: Ch. putoria Wiedemann, 1830, C: Ch. rufifacies Macquart, 1842, D: Fannia ornata (Meigen, 1826) (=Anthomyia ornata) Bigot, 1885, E: Lucilia spp. Robineau-Desvoidy, 1830, F: L. elongata Shannon, 1924, G: L. eximia Wiedemann, 1819, H: L. illustris Meigen, 1826, I: Musca autumnalis De Geer, 1776, J: Mu. (Musca) domestica Linnaeus, 1758, K: Muscina levida (Harris, 1780) = Ms. assimilis Fallén, 1823, L: Ms. pabulorum (Fallén, 1817) (=Muscina prolapsa Harris, 1780, M: Phormia regina Meigen, 1826, N: Sarcophaga (Bercaea) africa Wiedemann, 1824.*

Table 5. *Kendall tau correlation between flies collected in four sampling localities (208 sampling units: 52 sampling units from Bilongué, Ndakat, Ndogbong and Sobum respectively).*

Species 1/species 2	*Tau*	Species 1/species 2	Tau	Species 1/species 2	*Tau*	Species 1/species 2	*Tau*
Chrysomya puttoria /		*Ch. ruffifacies* /		*Lucilia* spp. /		*L. illustris* /	
Ch. megacephala	-0.321 *	*F. ornata*	0.158 *	*Po. regina*	0.188 *	*Mu. domestica*	0.227 *
Ch. ruffifacies	-0.304 *	*Lucilia* spp.	0.056 ns	*Mu. automnalis*	0.225 *	*Ms. pabulorum*	-0.199 *
Fannia ornata	-0.197 *	*..L. elongata*	-0.112 ns	*Mu. domestica*	0.007 ns	*Ms. assimilis*	0,378 *
Lucilia spp.	0.238 *	*L. eximia*	0.403 *	*Ms. pabulorum*	0.248 *	*Sa. africa*	-0,031 ns
..L. elongata	-0.222 *	*L. illustris*	0.109 ns	*Ms. assimilis*	0.034 ns	*Po. regina* /	
L. eximia	-0.181 *	*Po. regina*	0.098 ns	*Sa. africa*	0.244 *	*Mu. automnalis*	0.068 ns
L. illustris	-0.100 ns	*Mu. automnalis*	0.485 *	*L. elongata* /		*Mu. domestica*	0.317 *
Phormia regina	0.202 *	*Mu. domestica*	0.117 ns	*L. eximia*	-0.091 ns	*Ms. pabulorum*	0.184 *
Musca automnalis	-0.026 ns	*Ms. pabulorum*	0.280 *	*L. illustris*	-0.078 ns	*Ms. assimilis*	-0.152 *
Mu. domestica	-0.059 ns	*Ms. assimilis*	0.032 ns	*Po. regina*	0.065 ns	*Sa. Africa*	0.233 *
Muscina pabulorum	0.025 ns	*Sa. africa*	0.328 *	*Mu. automnalis*	-0.112 ns	*Mu. automnalis* /	
Ms. assimilis	0.121 ns	*F. ornata* /		*Mu. domestica*	0.282 *	*Mu. domestica*	0.118 ns
Sarcophaga africa	-0.278 *	*Lucilia* spp.	0.132 ns	*Ms. pabulorum*	0.348 *	*Ms. pabulorum*	0.427 *
Ch. megacephala /		*..L. elongata*	0.060 ns	*Ms. assimilis*	-0.153 *	*Ms. assimilis*	0.154 *
Ch. ruffifacies	0.262 *	*L. eximia*	0.239 *	*Sa. africa*	0.417 *	*Sa. africa*	0.289 *
F. ornata	0.143 *	*L. illustris*	0,104 ns	*L. eximia* /		*Mu. domestica* /	
Lucilia spp.	0.033 ns	*Po. regina*	0.089 ns	*L. illustris*	-0,074 ns	*Mu. pabulorum*	0.199 *
..L. elongata	0.358 *	*Mu. automnalis*	-0.092 ns	*Po. regina*	0.234 *	*Ms. assimilis*	-0.014 ns
L. eximia	0.502 *	*Mu. domestica*	0.269 *	*Mu. automnalis*	0.120 ns	*Sa. africa*	0.242 *
L. illustris	0.107 ns	*Ms. pabulorum*	0.042 ns	*Mu. domestica*	0.098 ns	*Ms. pabulorum* /	
Po. regina	0.211 *	*Ms. assimilis*	-0.027 ns	*Ms. pabulorum*	0.277 *	*Ms. assimilis*	-0.023 ns
Mu. automnalis	0.118 ns	*Sa. africa*	0.286 *	*Ms. assimilis*	-0.144 *	*S. africa*	0.391 *
Mu. domestica	0.319 *	*Lucilia* spp. /		*Sa. africa*	0.237 *	*Ms. assimilis* /	
Ms. pabulorum	0.203 *	*..L. elongata*	-0.123 ns	*L. illustris* /		*Sa. africa*	-0.134 ns
Ms. assimilis	-0.075 ns	*L. eximia*	0.191 *	*Po. regina*	-0.096 ns		
Sa. africa	0.447 *	*L. illustris*	-0.189 *	*Mu. automnalis*	-0.091 ns		

ns: not significant correlation (p-value>0.05), *: significant correlation (p-value<0.05), significant correlations are in bold.

Po. regina was dominant in Bilongué, Ndakat and Ndogbong and was simply abundant in Souboum. It was collected each hour of the day, with two daily activity peaks at 8 a.m. and 1 p.m. (Figure 5M). *Sa. (Bercaea) africa* was rare in Bilongué, Ndakat market and Ndogbong but dominant within the global assemblage. It was collected at 7 a.m., from 10 a.m. to 4 p.m. and at 6 p.m. (Figure 5N).

3.5. Between Species Association and Correlations

Overall, the species from the four localities, exhibited a global positive net association in presence/absence data (208 sample units, 5166 specimens belonging to 14 species, six to 1876 specimens collected, mean ± se: 369 ± 149 specimens, Schluter's Variance ratio: VR = 1.913, Statistic: W = 397.90, df = 14, p <0.001).

Based on the correlation results between the 14 species (Table 5) it was found that the accidental human myiasigenic fly *Ch. putoria* (Chrysomyiinae) was positively correlated with two species [*Lucilia* spp. (Calliphorinae) ($\tau = 0.238$, $p = 4.7\text{x}10^{-4}$) and *Po. regina* (Chrysomyiinae) ($\tau = 0.202$, $p = 3.0\text{x}10^{-3}$)] and negatively correlated with six species [*Ch. megacephala* (Chrysomyiinae) (Kendall correlation: $\tau = -0.321$, $p = 2.5\text{x}10^{-6}$), *Ch. ruffifacies* (Chrysomyiinae) ($\tau = -0.304$, $p = 8.1\text{x}10^{-6}$), *F. ornata* (Fanniinae) ($\tau = -0.197$, $p = 3.9\text{x}10^{-3}$), *L. elongata* (Calliphorinae) ($\tau = -0.222$, $p = 1.1\text{x}10^{-3}$), *L. eximia* (Calliphorinae) ($\tau = -0.181$, $p = 7.9\text{x}10^{-3}$) and *Sa. (Bercaea) africa* (Sarcophaginae) ($\tau = -0.278$, $p = 4.7\text{x}10^{-5}$).

The accidental human myiasigenic fly *Ch. megacephala* was positively correlated with eight species [*Ch. ruffifacies* ($\tau = 0.262$, $p = 1.2\text{x}10^{-4}$), *F. ornata* ($\tau = 0.143$, $p = 0.035$), *L. elongata* ($\tau = 0.358$, $p = 1.5\text{x}10^{-7}$), *L. eximia* ($\tau = 0.502$, $p = 1.9\text{x}10^{-13}$), *Po. regina* ($\tau = 0.211$, $p = 2.0\text{x}10^{-3}$), *Mu. (Musca) domestica* ($\tau = 0.319$, $p = 2.8\text{x}10^{-6}$), *Ms. pabulorum* ($\tau = 0.203$, $p = 2.9\text{x}10^{-3}$) and *Sa. (Bercaea) africa* ($\tau = 0.447$, $p = 5.6\text{x}10^{-11}$)]. The accidental human myiasigenic fly *Ch. ruffifacies* was positively correlated with five species. These species fly were *F. ornata* ($\tau = 0.158$, $p = 0.021$), *L. eximia* ($\tau = 0.403$, $p = 3.5\text{x}10^{-9}$), *Mu. autumnalis* (Muscinae) ($\tau = 0.485$, $p = 1.2\text{x}10^{-12}$), *Ms. pabulorum* (Muscinae) ($\tau = 0.280$, $p = 3.9\text{x}10^{-5}$) and *Sa. (Bercaea) africa* ($\tau = 0.328$, $p = 1.5\text{x}10^{-6}$). The accidental human myiasigenic fly *F. ornata* was positively associated with three species [*L. eximia* ($\tau = 0.239$, $p = 4.6\text{x}10^{-4}$), *Mu. (Musca) domestica* ($\tau = 0.269$, $p = 8.0\text{x}10^{-5}$) and *Sa. (Bercaea) africa* ($\tau = 0.286$, $p = 2.8\text{x}10^{-5}$)]. The accidental human myiasigenic fly *Lucilia* spp. was negatively correlated with *L. illustris* ($\tau = -0.189$, $p = 5.5\text{x}10^{-3}$) and positively correlated with five species [*L. eximia* ($\tau = 0.191$, $p = 5.0\text{x}10^{-3}$), *Mu. autumnalis* ($\tau = 0.225$, $p = 9.8\text{x}10^{-4}$), *Ms. pabulorum* ($\tau = 0.248$, $p = 2.8\text{x}10^{-4}$), *Po. regina* ($\tau = 0.188$, $p = 5.8\text{x}10^{-3}$) and *Sa. (Bercaea) africa* ($\tau = 0.244$, $p = 3.5\text{x}10^{-4}$)]. The obligate myiasigenic fly in anurans *L. elongata* was negatively correlated with *Ms. levida* (= *Ms. assimilis*) ($\tau = -0.153$, $p = 0.025$) and positively correlated with three species [*Mu. (Musca) domestica* ($\tau = 0.282$, $p = 3.5\text{x}10^{-5}$), *Ms. pabulorum* ($\tau = 0.348$, $p = 3.3\text{x}10^{-7}$) and *Sa. (Bercaea) africa* ($\tau = 0.417$, $p = 9.7\text{x}10^{-10}$)]. The accidental human myiasigenic fly *L. eximia* was negatively correlated with *Ms. levida* (= *Ms. assimilis*) ($\tau = -0.144$, $p = 0.035$) and positively

correlated with three species [*P. regina* (τ = 0.234, p = $5.9x10^{-4}$), *Ms. pabulorum* (τ = 0.277, p = $4.8x10^{-5}$) and *Sa. (Bercaea) africa* (τ = 0.237, p = $5.0x10^{-4}$)]. The accidental human myiasigenic fly *L. illustris* was negatively correlated with *Ms. pabulorum* (τ = -0.199, p = $3.5x10^{-3}$) and positively correlated with two species [*Mu. (Musca) domestica* (τ = 0.227, p = $8.8x10^{-4}$) and *Ms. levida* (=*Ms. assimilis*) (τ = 0.378, p = $2.9x10^{-8}$)]. The accidental human myiasigenic fly *Po. regina* was negatively correlated with *Ms. levida* (=*Ms. assimilis*) (τ = -0.152, p = 0.026). It was positively correlated with three species [*Mu. (Musca) domestica* (τ = 0.317, p = $3.4x10^{-6}$), *Ms. pabulorum* (τ = 0.184, p = $7.0x10^{-3}$) and *S. africa* (τ = 0.233, p = $6.2x10^{-4}$)]. The veterinary important fly *Mu. autumnalis* was positively correlated with three species [*Ms. pabulorum* (τ = 0.427, p = $3.8x10^{-10}$), *Ms. levida* (= *Ms. assimilis*) (τ = 0.154, p = 0.024) and *S. africa* (τ = 0.289, p = $2.3x10^{-5}$)]. The veterinary important fly *Mu. (Musca) domestica* was positively correlated with two species [*Ms. pabulorum* (τ = 0.199, p = $3.6x10^{-3}$) and *S. africa* (τ = 0.242, p = $3.9x10^{-4}$)]. The veterinary important fly *Ms. pabulorum* was positively correlated with *Sa. (Bercaea) africa* (τ = 0.391, p = $1.0x10^{-8}$). The other correlations were not significant.

4. Discussion

4.1. Species Richness, Abundance and Dominance

Our studies revealed the presence in Douala city of 14 species of non-biting flies, eight genera, five subfamilies, and four families of Brachycera (Diptera). Based on the collection, Calliphoridae family represented more than 86.2% of the total collection devided into two subfamilies: Chrysomiinae (66.9%) and Calliphorinae (19.3%). This family was followed by Muscidae family (Muscinae subfamily) (13.3%) while Fanniidae family (Fanniinae subfamily) and Sarcophagidae family (Sarcophaginae subfamily) were rarely represented respectively 0.1% and 0.7% of the total collection. These flies were all facultative myiasigenic species [28, 71-79, 81-85, 87-99, 100-103, 128,]. Despite the permanent and abundant decaying household waste in the study localities, the presence of roaming domestic animals (dogs, cats and goats), pig farms and chicken coops next to or even inside houses (pers. obs.), only six species were recorded active at any time of the day. These flies were the Calliphorinae *Lucilia* spp., three Chrysomyiinae [*Ch. putoria, Ch. rufifacies* and *Po. regina*], and two Muscinae [*Mu. (Musca) domestica* and *Ms. pabulorum* (=*Ms. prolapsa*)]. *Lucilia* flies (Green Flies) are worldwide distributed, relatively small in sized, metallic green-blue colour, mainly saprophagous and necrophagous [72-74, 76, 77]. Amongst them less numerous optional ectoparasite species are repported [case of the Holarctic origin common green bottle fly *L. sericata* (Meigen, 1826) as common visitor to carrion, feces, and garbage and important species in forensic, medical and veterinary science [72, 131] and the Australian sheep blow fly *L. cuprina* (Diptera: Calliphoridae) known to induce primary ovine cutaneous myiasis in many parts of the world [28] and to a lesser extent, the Paleartic origin green bottle fly *L. caesar* and the cosmopolitan green bottle fly *L. illustris* both known to be of forensic, medical and veterinary importance since they affect mammals (mainly sheep and rarely other wild and domestic animals and even humans) [132]. Other species, very rare, are highly specialized obligate ectoparasites (case of the toat fly *L. bufonivora* Moniez, 1876 causing myiasis in toads) [133]. The adults of *Lucilia* species are flower-dwellers and then good pollinator species [134]. Their abundant presence in the localities of the study is therefore not surprising given that the favorable conditions are met for their multiplication. The tropical African latrine blowfly *Ch. putoria* pose significant health risks, especially due to their close association with human settlements since adults can carry pathogens while larvae cause myiasis of domestic animals and humans [71, 94]. Due to the appearance of the Australian hairy maggot blowfly *Ch. rufifacies* and the holarctic black blowfly *Po. regina* in cadaveric remains, they play a fundamental role in forensic entomology [130, 135-137]. In subsaharan African countries, the worldwide synanthropic housefly *Mu. (Musca) domestica* is known involved in the transmission of diseases of the faecal danger, behaving as a mechanical vector of pathogens (bacteria, fungi, viruses, and parasites), some of which cause serious diseases in humans and domestic animals [100, 101, 138-140]. *Ms. pabulorum* (=*Ms. prolapsa*) is a cosmopolitan species found in far north Europe as well as tropical countries, sometimes recovered from human remains [95, 96; 141] but their potential as indicators of the post-mortem interval has been exploited only occasionally [142]. These particularly abundant flies, very active throughout the day, could have a similar impact in the city of Douala. In addition eight species were rarely recorded only for a few hours during the day. These species were three Calliphorinae (Calliphoridae) (*L. elongata, L. eximia* and *L. illustris*), the Chrysomyiinae (Calliphoridae) *Ch. megacephala,* the Fanniinae (Fanniidae) *F. ornata* (=*A. ornata*), two Muscinae (Muscidae) (*Mu. autumnalis* and *Ms. levida* (=*Ms. assimilis*) and the Sarcophaginae (Sarcophagidae) *Sa. (Bercaea) africa.* Each of them behaves like the species of the same genus or the same subfamily presented above. In North America, all cases of anuran myiasis were attributed to L. silvarum (Meigen) or L. elongata [72, 76, 129]. The latter species is exceedingly rare and its life history is unknown [129]. The Brazilian native fly *L. eximia* is a forensically important blow fly usually found on carrion during the fresh and bloated stages of decomposition rather than resources in advanced decay stage [143]. The Australasian origin species *Ch. megacephala* occurs on every continent and is closely associated with carrion and decaying material in human environments. Its abilities to find dead bodies and carry pathogens give it a prominence in human affairs that may involve prosecution or litigation, and therefore forensic entomologists [144]. The European house fly *F. ornata* (=*A. ornata*) behaves like the other Fannidae species presented above [145]. The Paleactic face fly or autumn housefly *Mu. autumnalis* is a pest of cattle

and horses, feeding at the eyes and faces of host animals in the temperate regions of the northern hemisphere [102]. Three representatives of the *Muscina* genus (*Ms. levida*, *Ms. prolapsa* and *Ms. stabulans*) are well known for their medical and veterinary importance demonstrated by the occurrence of myiasis in humans and animals [28]. Larvae of *Muscina* are facultative carnivores and adults are vectors of pathogens [146]. *Ms. levida* is a wordwide species reported in dead snails but it's native range is still unknown [147]. The flesh fly *Sa. (Bercaea) africa* is an other forensically important dominant fly in Europe [148-151]. We did not capture any obligate human myiasigenic species. But in two veterinary clinics located in two localities in Douala (Mbopi and Bonabéri), we found two sick female dog from whom we extracted one to six larvae (4 ± 3 larvae per boil) of *Cordylobia anthropophaga* Blanchard & Berenger-Feraud, 1872 (Diptera: Calliphoridae), for a prevalence of 2.0% (unpublised data), suggesting that this species was rare and have escaped our collection campaigns.

The low diversity of the non-biting flies was associated with low abundance in native species (three species i.e. 21.4% of the total species richness and 37.6% of the total flies abundance), suggesting the weak exploitation of resources by the afrotropical species. These native species were *Ch. putoria* (Calliphoridae: Chrysomyiinae), *F. ornata* (=*A. ornata*) (Fanniidae: Fanniinae) and *Sa. (Bercaea) africa* (Sarcophagidae: Sarcophaginae). The exploitation of both food and nest sites was mostly achieved by non-native species (neine non-native species i.e. 64.3% of the total species richness and 43.7% of the total abundance). Exotic species were devided into two Australasian Chrysomyiinae (Calliphoridae) (14.3%) [*Ch. megacephala* and *Ch. rufifacies*], the Holearctic Chrysomyiinae (Calliphoridae) *Po. regina* (7.1%), the Nearctic Calliphorinae (Calliphoridae) *L. elongata* (7.1%), the Neotropical Calliphorinae (Calliphoridae) *L. eximia* (7.1%), four Palearctic Muscinae (Muscidae) [*Mu. autumnalis, Mu. (Musca) domestica, Ms. (=Ms. assimilis)* and *Ms. pabulorum* (=*Ms. prolapsa*)]. Finally two Calliphorinae (Calliphoridae) (14.3% of the total species richness and 18.7% of the total abundance) were only known as wordwide distributed. These species were *Lucilia* spp. and *L. illustris*. The high abundance level of the invasive alien species in their introduced range is well known in insect communities [152, 153]. The recorded native and alien species are frequently reported as pests damaging the health of humans and livestock. The low representation of native species could be the result either of the regulation of their populations by local natural enemies, or of a negative force of introduced species. The role of synanthropic non-biting flies in the epidemiology of human infectious diseases is well known not only in their native range but also in areas of introduction, since their feeding and reproductive habits make them mechanical vectors of pathogens. They are major epidemiologic factors responsible for the spread of acute gastroenteritis and trachoma among infants and young children in (predominantly) developing countries and they are involved in mechanical transmission of nosocomial infections with multiple antibiotic-resistant bacteria in hospital environments [154]. Based on the reports concerning the harmful activity of exotic non-biting flies in the localities of introduction, they would carry out a similar activity in Douala.

Our results were contrary to those reported in the Jos Museum Zoological Garden, north central Nigeria [59] where the worldwide medical and veterinary importance obligate blood feeder (stable fly) *Stomoxys calcitrans* (Linnaeus, 1758) (Muscidae: Muscinae) was the most abundant and there were significantly more flies in the Lion, Bovidae (Donkey, Carmel and Horse) and Ostrich sites compared to Human routes, in Woreta northwestern Ethiopia [155]. Non-biting flies identified by these last authors were the house fly *Mu. domestica* (Muscidae: Muscinae) (32.9%), *Ch. rufifacies* (Calliphoridae: Chrysomyiinae) (32.6%), the bazaar fly *Mu. sorbens* Wiedemann, 1830 (Muscidae: Muscinae) (23%), the Australian sheep blowfly *L. cuprina* (Wiedemann, 1830) (Calliphoridae: Calliphorinae) formerly named *Phaenicia cuprina* Wiedemann, 1830 (Calliphoridae: Calliphorinae) (4.7%), the forensically important blue bottle fly *Calliphora vicina* Robineau-Desvoidy, 1830 (Calliphoridae: Calliphorinae) (2.8%), the obligate parasitic screwworm *Ch. bezziana* (Villeneuve, 1914) (Calliphoridae: Chrysomyiinae) (2.3%) and the obligate parasitic spotted flesh fly *Wohlfahrtia magnifica* (Schiner, 1862) (Sarcophagidae: Paramacronychiinae) (1.7%). In Malaysia a similar study carried out in wet markets [156] showed that of 1,158 specimens of collected flies belonging to 15 species, the highest number of species was found from the family Muscidae, while individuals of the family Calliphoridae were the highest in number, of which the most prominent was the Chrysomiinae species *Ch. megacephala,* the highest number of flies (52% and 12 species) being sampled in garbage piles. Acording to the same authors, fresh markets in Malysia were potential places for breeding of disease spreading flies if proper sanitation practices were not applied. A detailed historical compendium of the different fly control methods was developped [134] but we cannot encourage the inappropiate use of synthetic chemical pesticides because of many unwanted effects such as environmental pollution, non-target effect and human health hazards and the development of resistance. A similar situation would arise in Douala city if the phytosanitary authorities do not take adequate measures to educate populations and protect the environment.

In Douala city (Littoral-Cameroon), the non-biting fly species richness (7,379 specimens, 14 species, seven genera, five subfamilies and four families) is closed to the above presented results from Malaysia [155], those from Bufalo farms in Beranang, Selangor, Malaysia where from 2,775 fly specimens collected 11 species of muscids were identified and three of them were haematophagic namely *Mu. conducens* Walker, 1859, *Mu. crassirostris* Stein, 1903, and *Stomoxys calcitrans* (Linnaeus) [157]. Our results were closed to the above presented results from Ethiopia [156] and lower than that reported in the Kabylia region of Algeria, where 631 captured flies belonged to 26 species, 15 genera

and 8 families. Of them, eight species [*Ca. vicina*, *Ca. vomitoria* Linnaeus, 1758, *L. sericata*, *L. ampullaceal* Villeneuve, 1922, *Sa. (Bercaea) africa*, *Sa. carnaria* Linnaeus, 1758, *Mu. (Musca) domestica* and *F. canicularis* Linnaeus, 1761] were pathogenic agents of various animal and human myiasis [5, 21, 22, 158]. The non-biting fly assemblage recorded in Douala was certainly underestimated.

4.2. Community Structure

On the base of the AIC values, non-biting flies assemblage from Bilongué, Ndogbong and Souboum localities and the global assemblage best fitted the GM nomocenose model, with the the Motomura's environmental constant reaching high values (0.485, 0.715, 0.415 and 0.646 respectively). The GM's model (niche pre-emption) corresponds to a community in which a reduced number of species largely dominante the assemblage (pioneer assemblages) [159]. This model is reported fitting SADs from several insect communities as the case of sandflies in Mayombe region (Congo) [160], ground-nesting ants in Douala (Cameroon) [104], Carabids and Heteroptera inhabiting roadsides and managed grassland pairs in central Finland [161], insects associated with the African eggplant *Solanum aethiopicum* L., 1756 (Solanales: Solanaceae) [162], insects associated with the potato *Solanum tuberosun* L., 1753 (Solanales: Solanaceae) [163], and grasshoppers in different vegetation types in the Littoral of Cameroon [164]. This model therefore seems to characterize the stands of open forests and disturbed environments (case of urban areas), where there is strong competition between pioneer species for the exploitation of available resources.

In Ndakat market (Ndokoti), non-biting fly community exhibited the Preston's lognormal nomocenosis model (Preston's niche partitioning model) with a very high environmental constant (m' = 3.587). Unlike the Motomura's model, the Preston's model describes the relationship between the logarithm of abundance and the probit of species rank and reflects a community where the majority of species show moderate abundances. Through literature, the lognormal is reported fitting the abundance distribution of several invertebrate communities including snails [165-167] and insects inhabiting climax and paraclimax environments [161, 164, 168]. This model therefore characterizes the stands of open or less disturbed environments. Human activities in general resulting in urbanization and growing cities have been reported to to affect ecosystem functioning and to contribute to the loss of biodiversity [169]. Our results therefore show that the community of non-biting flies sampled at the Ndakat market (Ndokoti) has, despite the intense human disturbance characterized by notorious insalubrity, developed, as is the case of the above documented communities of invertebrates, a model close to that of little disturbed environments.

5. Conclusion

The disadvantaged neighborhoods of Douala (Littoral Cameroon) are largely invaded by alien non-biting medically, veterinary and forensically important flies. In these localities, all the conditions combine to soar. Due to the numerical and behavioral dominance of alien flies, a significant number of resources are potentially exploitable. In due course, once the invaders would completely monopolize available resources and saturate the locality, they would not allow native species the niche opportunities to re-establish themselves. This would expose the population and livestock to myiasigenic attacks and therefore the increase in the prevalence of this neglected tropical pathology. The consequences of loosing native species, which may well interact with the endemic fauna, will be of extreme concern. The high occurence of pest flies necessitates the reaction of the national public health control service to reduce myiasis occurrence in the city.

Acknowledgements

The authors acknowledge the Cameroonian Ministry of Higher Education for providing funds through the research support program. They thank the inhabitants of the sampling urban localities in Douala, the administrative authorities of the University of Douala and the health center of Souboum, the traders of Ndokoti (Ndakat) for having allocated us space for catching flies.

References

[1] Abbas, M. N., Sajeel, M. & Kausar, S. (2013). House fly (*Musca domestica*), a challenging pest: biology, management and control strategies. Elix. Entomol., 64: 19333-19338.

[2] Hinkle, N. C.; Hogsette, J. A. A (2021). Review of Alternative Controls for House Flies. Insects, 12: 1042.

[3] Geden, C. J., Nayduch, D., Scott, J. G., Burgess, E. R., Gerry, A. C., Kaufman, P. E., Thomson, J., Pickens, V. & Machtinger, E. T. (2021). House Fly (Diptera: Muscidae): Biology, Pest Status, Current Management Prospects, and Research Needs. J. Integr. Pest Manag., 12 (1): 39: 1-38.

[4] Awache, I., Farouk, A. A. (2016). Bacteria and fungi associated with houseflies collected from cafeteria and food centres in Sokoto. Fuw. Trends Sci. Technol. J., 1 (1): 123-126.

[5] Ourradi, O., Ahmed, D. S.-A., Sadou, S.-A., Bouzrarf, K. & Belqat, B. (2022). Diversity of flies (Diptera: Brachycera) in breeding farms in the Kabylia region (North-central Algeria), and identification of some myiaseginic species. Biodiversitas, 23 (5): 2276-2284.

[6] Sawar, M. (2015). Biological Control Program to Manage Fruit Fly Pests and Related Tephritids (Diptera: Tephritidae) in Backyard, Landscape and Garden. Int. J. Anim. Biol., 1 (4): 118-123.

[7] Hack, R. J. (2019). Fly control: reducing disease and productivity losses. Int. dairy topics, 18 (2): 13-15.

[8] Meerburg, B. G., Vermeer, H. M. & Kijlstra, A. (2007). Controlling risks of pathogen transmission by flies on organic pig farms A review. Outlook Agric., 36 (3): 193–197.

[9] Radonjić, S., Hrnčić, S. & Perović, T. (2019). Overview of fruit flies important for fruit production on the Montenegro seacoast. Biotechnol. Agron. Soc. Environ., 23 (1): 46-56.

[10] Salazar-Mendoza, P., Peralta-Arago, I., Romero-Rivas, L., Salamanca, J., Rodriguez-Saona, C. (2021) The abundance and diversity of fruit flies and their parasitoids change with elevation in guava orchards in a tropical Andean forest of Peru, independent of seasonality. PLoS ONE, 16 (4): e0250731.

[11] Hinkle, N. C.; Hogsette, J. A. (2021). A Review of Alternative Controls for House Flies. Insects, 12: 1042.

[12] Mitra, B., Parui, P., Banerjee, D., Mukherjee, M. & Bhattachaejee, K. (2005). A Report on Flies (Diptera: Insecta) as Flower Visitors and Pollinators of Kolkata and it's adjoining areas. Rec. Zool. Surv. India, 105 (3-4): 1-20.

[13] Farkas, R. & Papp, L. (1990). *Hydrotaea (Ophyra)* species as potential biocontrol agents against *Musca domestica* (Diptera) in Hungary, Pp. 169-176. In: Rutz, D. A. & Patterson, R. S. (eds.). *Biocontrol of Arthropods affecting livestock and poultry*. Westview Publisher, Westview Boulder.

[14] Farkas, R., Hogsette, J. A. & Borzsonyi, L. (1998). Development of *Hydrotaea aenescens* (Wiedemann) and *Musca domestica* L. (Diptera: Muscidae) in poultry and pig manure of different moisture content. Environ. Entomol., 27: 695-699.

[15] Hogsette, J. A. & Jacobs, R. D. (1999). Failure of *Hydrotaea aenescens*, a larval predator of the house fly, *Musca domestica* L., to establish in wet poultry manure on a commercial farm in Florida USA. Med. Vet. Entomol., 13: 349-354.

[16] Simon, P. P., Krüger, R. F. & Ribeiro, P. B. (2011). Influence of diets on the rearing of predatory flies of housefly larvae. Arq. Bras. Med. Vet. Zootec., 63 (6): 1414-1420.

[17] Dieng, H., Satho, T., Mohd Radzi, N. H. S. B., Abang, F., Kassim, N. F. A., Zuharah, W. F., Hashim, N. A., Morales Vargas, R. E. & Morales, N. P. (2021). Flower Mimics Roll Out Multicolored Carpets to Lure and Kill the House Fly. Insects, 12: 1097.

[18] El-Hawagry, M. S. (2018). Catalogue of the Tachinidae of Egypt (Diptera: Oestroidea). Egypt. J. Biol. Pest Control., 28: 46.

[19] Ebrahim, A. M. & Nada, M., S. (2021). First record of *Cylindromyia (Conopisoma) rufipes* of subfamily Phasiinae (Tachinidae: Diptera) as facultative endoparasitoid of *Nezara millierei* (Pentatomidae: Hemiptera) in Egypt. Egypt. J. Plant Prot. Res. Inst., 4 (1): 17-28.

[20] Clarke, A. R., Armstrong, K. F., Carmichael, A. E., Milne, J. R., Raghu, S., Roderick, G. K. & Yeates, D. K. (2005). Invasive Phytophagous Pests Arising Through a Recent Tropical Evolutionary Radiation: The *Bactrocera dorsalis* Complex of Fruit Flies. Annu. Rev. Entomol., 50: 293-319.

[21] Buck, M. (2010). Neriidae, Pp. 815-819. In: Brown, V., Borkent, A., Cumming, J. M., Wood, D. M., Woodley, N. E. & Zumbado, M. A. (eds.). *Manual of Central American Diptera.* NRC Research Press, Ottawa.

[22] Queiroz, C. L. D., De-Souza, C. C., Medeiros, H. F., Overal, W. L., Viana-Junior, A. B. & Carvalho Filho, F. S. (2021). Saprophytic flies in impacted areas of the Belo Monte Dam, Pará, Brazil (Diptera: Mesembrinellidae, Neriidae, Ropalomeridae, and Sarcophagidae): community composition, abundance, and species richness. Biota Neotropica, 21 (1): e20201026.

[23] Salazar-Ortega J. A. & Gomez-Piñerez E. A. L. M. (2012). A check list of necrophagous flies (Diptera: Calyptratae) from urban area in Medellín, Colombia. Rev. Mex. Biodivers., 83: 562-565.

[24] Hanski, I. (1987). Carrion fly community dynamics: patchiness, seasonality and coexistence. Ecol. Entomol., 12: 257-266.

[25] Skevington, J. H. & Dang, P. T. (2002). Exploring the diversity of flies (Diptera). Biodiversity, 3: 1-2.

[26] Brown, B. V., Marshall S. A. & Wood, D. M. (2009). Natural History, Pp. 51-63. In: Brown B., Borkent, A., Cumming, J. M., Wood, D. M., Woodley, N. E. & Zumbado, M. A. (eds.). *Manual of Central American Diptera*. NCR Research press, Ottawa.

[27] Adrianto, H., Ansori, A. N. M., Bendryman, S. S. & Arwati, H. (2021). Comparison of meat as trap bait for adult fly collection and control. Nat. Vol. Essent. Oil, 8 (6): 641-646.

[28] Zumpt, F. (1965). *Myasis in Man and Animals in the Old World: A textbook for Physicians, Veterinarians and Zoologists.* Butterworths & Co. Ltd, London, Pp 267.

[29] Hall, M. & Wall, R. (1995). Myiasis of humans and domestic animals. Adv. Parasitol., 35: 257-334.

[30] Tligui, H., Bouazzaoui, A. & Agoumi, A. (2007). Otomyiases humaines dues à *Wohlfahrtia magnifica* (Diptera: Sarcophagidae): à propos de trois observations au Maroc. Bull. Soc. Pathol. Exot., 100 (1): 61-64.

[31] Francesconia, F. & Lupi, O. (2012). Myiasis. Clin. Microbiol. Rev., 25: 79-105.

[32] Beyhani, Y. E., Yilmazi, H., Taş-Cengizi, Z. & Ayral, A. (2017). A case of aural myiasis caused by *Wohlfahrtia magnifica* in a child in Turkey. Turk. Hij. Den. Biyol. Derg., 74 (4): 347-350.

[33] Hosni, E. M., Kenawy, M. A., Nasser, M. G., Al-Ashaal, S. A. & Rady, M. H. (2019). A Brief Review of Myiasis with Special Notes on the Blow Flies' Producing Myiasis (F.: Calliphoridae). Egypt. Acad. J. Biolog. Sci., 11 (2): 25-32.

[34] Hall, M. J., Wall, R. L. & Stevens, J. R. (2016). Traumatic myiasis: a neglected disease in a changing world. Annu. Rev. Entomol., 61: 159-176.

[35] Evenhuis, N. L. & Pape, T. (2022). Systema Dipterorum. In Bánki O., Roskov Y., Döring M., Ower G., Vandepitte L., Hobern D., Remsen D., Schalk P., DeWalt R. E., Keping M., Miller J., Orrell T., Aalbu R., Adlard R., Adriaenssens E. M., Aedo C., Aescht E., Akkari N., Alfenas-Zerbini P. et al. (eds.). *Catalogue of Life Checklist (3.6, Feb 2022)*. www.catalogueoflife.org/data/dataset/1101. Accessed on 13th Jun 2022.

[36] Singh, A. & Singh, Z. (2015). Incidence of myiasis among humans-a review. Parasitol. Res., 114: 3183-3199.

[37] Sherman R. A. (2000). Wound Myiasis in Urban and Suburban United States. Arch. Intern. Med., 160: 2004-2014.

[38] Bhagat, R. C. (2016). Biodiversity of Dipterous flies (Insecta) of myiasis–causing importance in animals and human of Jammu, Kashmir and Ladakh Himalayas (India). J. Glob. Biosci., 5 (7): 4341-4349.

[39] Andriotti, P. A., Souza, C. P., Oliveira, P. C., Melo, R. C., Verocai, G. G. & Fernandes, J. I. (2021). Effectiveness of sarolaner in the clinical management of furuncular myiasis in dogs naturally infested with *Dermatobia hominis* (Diptera: Cuterebridae). Parasites Vectors, 14: 401.

[40] Máca, J. & Otranto, D. (2014). Drosophilidae feeding on animals and the inherent mystery of their parasitism. Parasites Vectors, 7: 516.

[41] Chigusa, Y., Shinonaga, S., Koyama, Y., Terano, A., Kirinoki, M. & Matsuda, H. (2000). Suspected intestinal myiasis due to *Dryomyza formosa* in a Japanese schizophrenic patient with symptoms of delusional parasitosis. Med. Vet. Entomol., 14 (4): 453-457.

[42] Huang, H., Zhang, B., Chu, H., Zhang, D. & Li K. (2016). *Gasterophilus* (Diptera, Gasterophilidae) infestation of equids in the Kalamaili Nature Reserve, China. Parasite, 23: 36.

[43] Martin-Vega, D. (2011). Skipping clues: forensic importance of the family Piophilidae (Diptera). Forensic Sci. Int., 212 (1-3): 1-5.

[44] El-Dib, N. A., El Wahab, W. M. A., Hamdy, D. A. & Ali, M. I. (2017). Case Report of Human Urinary Myiasis Caused by *Clogmia albipunctata* (Diptera: Psychodidae) with Morphological Description of Larva and Pupa. J. Arthropod Borne Dis., 11 (4): 533-538.

[45] El-Dib, N. A., Ali, M. I., Hamdy, D. A. & El Wahab, W. M. A. (2020). Human intestinal myiasis caused by *Clogmia albipunctata* larvae (Diptera: Psychodidae): First report in Egypt. J Infect. Public Health, 13 (4): 661-663.

[46] Dutto, M. & Bertero, M. (2010). Traumatic myiasis from *Sarcophaga (Bercaea) cruentata* Meigen, 1826 (Diptera, Sarcophagidae) in a hospital environment: Reporting of a clinical case following polytrauma. J. Prev. Med. Hyg., 51: 50-2.

[47] Manrique-Saide, P., Rodríguez-Vivas, R. I., Rodríguez, M. Q. & Quiroz-Aparicio R. (1999). A case of bovine pseudomyiasis caused by *Hermetia illucens* larvae (Diptera: Stratiomyidae). Rev. Biomed., 10 (3): 173-175.

[48] Pérez-Bañón, C., Rojas, C., Vargas, M., Mengual, X.& Rojo, S. (2020). A world review of reported myiases caused by flower flies (Diptera: Syrphidae), including the first case of human myiasis from Palpada scutellaris (Fabricius, 1805). Parasitol. Res., 119 (6): 815-840.

[49] Nagakura, K., Kawauichi-Kato, Y., Tachibana, H., Kaneda, Y., Shinonaga, S. & Kano, R. (1991). Three cases of intestinal myiasis in Japan. J. Infect. Dis., 163: 170-1171.

[50] Scholl, P. J. (1993). Biology and control of cattle grubs. Ann. Rev. Entomol., 39: 53-70.

[51] Caumes E, Carrière, J., Guermonprez, G., Bricaire, F., Danis, M., Gentilini, M. (1995). Dermatoses associated with travel to tropical countries - a prospective study of the diagnosis and management of 269 patients presenting to a tropical disease unit. Clin. Infect. Dis., 20: 542-548.

[52] Gabriel, J. G., Marinho, S. A., Verli, F. D., Krause, J. G., Yurgel, L. S. & Cherubini, K. (2008). Extensive myiasis infestation over a squamous cell carcinoma in the face. Med. Oral Patol. Oral Cir. Bucal, 13 (1): E9-11.

[53] Herbinger, K.-H., Siess, C., Nothdurft, H. D., von Sonnenburg, F. & Löscher, T. (2011). Skin disorders among travellers returning from tropical and non-tropical countries consulting a travel medicine clinic. Trop. Med. Int. Health, 16 (11): 1457-1464.

[54] Korzeniewski, K., Juszczak, D. & Jerzemowski, J. (2015). Skin lesions in returning travellers. Int. Marit. Health, 66 (3): 173-180.

[55] Andreatta, E. & Bonavina, L. (2021). Wound myiasis in Western Europe: prevalence and risk factors in a changing climate scenario. Eur. Surg., 1-6. 10.1007/s10353-021-00730-y.

[56] García-Romera, C. A. & Barrientos, J. A. (2017). Structure of scuttle fly communities (Diptera: Phoridae) in two habitats on a Mediterranean mountain. Eur. J. Entomol., 114: 203-214.

[57] Yaseen, A. T., Mohammed, D. A. & Aziz, E. M. T. (2021). Myiasis, its Types, Causes, and the relationship of some bacterial species to its events / (article review). Mesopotamia J. of Agric., 49 (1): 19-33.

[58] Kuria, S. K., Kingu, H. J. C., Villet, M. H. & Dhaffala, A. (2015). Human myiasis in rural South Africa is under-reported. S. Afr. Med. J., 105 (2): 129-133.

[59] Njila, H. L., David, S. & Ombugadu, A. (2015). Prevalence of biting and non-biting flies in relation to species in the Jos Museum Zoological Garden, North Central Nigeria. Bayero J. Pure Appl. Sci., 8 (1): 149-152.

[60] Omonona, A. O., Abioye, S. A., Odeniran, P. O. & Ademola, I. O. (2021). Catch Composition of Dipteran flies in Old Oyo National Park, Nigeria. Niger. J. Parasitol., 42 (1): 41-48.

[61] Kouam, M. K., Meutchieye F., Nguafack, T. T., Miegoué, E., Tchoumboué, J. & Theodoropoulos, G. (2015). Parasitic fauna of domestic cavies in the western highlands of Cameroon (Central Africa). BMC Vet. Res., 11: 288.

[62] Kouam, M. K., Meutchieye, F., Miegoue, E., NGuafack, T. T., Tchoumboue, J. & Teguia, A. N. D. A. (2017). Prevalence and husbandry-related risk factors of myiasis in domestic cavies in the western highlands of Cameroon. Epidemiol. Infect., 145: 339-346.

[63] Sevidzem, S. L., Mamoudou, A., Acapovi-Yao, G. L., Achiri, M., Tchuinkam, T., Zinga-Koumba. C. R. & Mavoungou, J. F. (2016). First Inventory of Non-Biting and Bitting Muscids of North Cameroon. Int. J. Biol. Sci., 5. 12-20.

[64] Sevidzem, S. L., Mavoungou, J. F., Zinga-Koumba, C. R., Koumba, A. A. & Duvallet, G. (2019). Factors Influencing Seasonal and Daily Dynamics of the Genus Stomoxys Geoffroy, 1762 (Diptera: Muscidae), in the Adamawa Plateau, Cameroon. Int. J. Zool., 9. ID 3636943.

[65] Vanhecke, C., NdiKweti Nguimfack, R., Lemarchand, J., Reichart, V. & Le Gall, P. (2015). Facial oedema caused by multifocal myiasis of Cordylobia rodhaini in Yaoundé – Cameroon. Presse Med., 44: 564-566.

[66] Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. (2006). World Map of the Köppen-Geiger climate classification updated. Meteorol. Zeitschrift, 15 (3): 259-263.

[67] Climate-Data.org (2019). Climat Douala (Cameroun). https://fr.climate-data.org/afrique/cameroun/ littoral/douala-890444/. Assessed on 10th September 2020.

[68] Barraclough, D. A. (1995). An illustrated identification key to the acalyptrate fly families (Diptera: Schizophora) occurring in southern Africa. Ann. Natal Mus., 36: 97-103.

[69] Couri, M. S. (2007). A key to the Afrotropical genera of Muscidae (Diptera). Rev. Bras. Entomol., 24 (1): 175-184.

[70] Buck, M., Woodley, N. E., Borkent, A., Wood, D. M., Pape, T., Vockeroth, J. R., Michelsen, V., & Marshall, S. A. (2009). Key to Diptera families - adults, Pp. 95-144. In: Brown, B. V., Borkent, A., Cumming, J. M., Wood, D. M., Woodley, N. E., & Zumbado, M. A. (eds.). *Manual of Central American Diptera*. Volume 1. NRC Research Press, Ottawa.

[71] Rognes, K. & Paterson, H. E. H. (2005). *Chrysomya chloropyga* (Wiedemann, 1818) and *C. putoria* (Wiedemann, 1830) (Diptera: Calliphoridae) are two different species. Afr. Entomol., 13 (1): 49-70.

[72] Whitworth, T. (2006). Keys to the genera and species of blow flies (Diptera: Calliphoridae) of America North of Mexico. Proc. Etomol. Soc. Wash., 108 (3): 689-725.

[73] Szpila, K. (2010). Key for the identification of third instars of European blowflies (Diptera: Calliphoridae) of forensic importance, Pp. 43-56. In: Amendt, J., Goff, M. L., Campobasso, C. P. & Grassberger, M. (eds.). *Current concepts in forensic entomology*. Springer, Dordrecht.

[74] Whitworth, T. (2010). Keys to the genera and species of blow flies (Diptera: Calliphoridae) of the West Indies and description of a new species of *Lucilia* Robineau-Desvoidy. Zootaxa, 2663: 1-35.

[75] Irish, S., Lindsay, T. & Wyatt, N. (2014). Key to Adults of Afrotropical Species of the Genus *Chrysomya* Robineau-Desvoidy (Diptera: Calliphoridae). Afr. Entomol., 22 (2), 297-306.

[76] Tantawi, T. & Whitworth, T. (2014). First record of *Lucilia bufonivora* Moniez, 1876 (Diptera: Calliphoridae) from North America and key to North American species of the L. bufonivora species group. Zootaxa, 3881 (2): 101-124.

[77] Whitworth, T. (2014). A revision of the Neotropical species of *Lucilia* Robineau-Desvoidy (Diptera: Calliphoridae). Zootaxa, 3810 (1): 001-076.

[78] Akbarzadeh, K., Wallman, J., Šuláková, H. & Szpila, K. (2015). Species identification of Middle Eastern blowflies (Diptera: Calliphoridae) of forensic importance. Parasitol. Res., 114. 10.1007/s00436-015-4329-y.

[79] Grzywacz, A., Hall, M. J. R., Pape, T. & Szpila, K. (2017a). Muscidae (Diptera) of forensic importance - an identification key to third instar larvae of the western Palaearctic region and a catalogue of the muscid carrion community. Int. J. Legal Med., 131: 855-866.

[80] Grzywacz, A., Ogiela, J. & Tofilski, A. (2017b). Identification of Muscidae (Diptera) of medico-legal importance by means of wing measurements. Parasitol. Res., 116: 1495-1504.

[81] Lutz, L., Williams, K. A., Villet, M. H., Ekanem, M. & Szpila, K. (2018). Species identification of adult African blowflies (Diptera: Calliphoridae) of forensic importance. Int. J. Legal Med. 132 (3): 831–842.

[82] Vahedi Nouri, N. & Salehi, A (2020). Myiasis in humans and animals. Anim. Husb. Dairy Vet. Sci, 4: 1-3.

[83] Vairo, K. P., de Mello-Patiu, C. A. & de Carvalho, C. J. B. (2011). Pictorial identification key for species of Sarcophagidae (Diptera) of potential forensic importance in southern Brazil. Rev. Bras. Entomol., 55 (3): 333-347.

[84] Verves, Y. G. (2005). A catalogue of Oriental Calliphoridae (Diptera). Int. J. Dipterol. Res., 16: 233-310.

[85] Sabrosky, C. W. (1999). Family-Group Names in Diptera. An Annotated Catalog, Pp. 3-360. In: Thompson F. C. (ed.). *Family-Group Names in Diptera and Bibliography*. MYIA Volume 10, Backhuys Publishers, North American Dipterists' Society, Leiden, Netherlands.

[86] Kosmann, C., de Mello, R. P., Harterreiten-Souza, É. S. & Pujol-Luz, J. R. (2013). A List of Current Valid Blow Fly Names (Diptera: Calliphoridae) in the Americas South of Mexico with Key to the Brazilian Species. EntomoBrasilis, 6 (1): 74-85.

[87] GBIF (2021). *Muscina prolapsa* (Harris, 1780). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei. Accessed via GBIF.org on 26th May 2022.

[88] Baumgartner, D. & Greenberg, B. (1984). The Genus *Chrysomya* (Diptera: Calliphoridae) in the New World. J. Med. Entomol., 21: 105-113.

[89] Baumgartner, D. L. (1988). Spread of introduced *Chrysomya* blowflies (Diptera: Calliphoridae) in the Neotropics with record new to Venezuela. Biotropica, 20: 167-168.

[90] Goff, M. L. (1991). Comparison of insect species associated with decomposing remains recovered inside dwellings and outdoors on the island of Oahu, Hawaii. J. Forensic Sci. 36: 748-753.

[91] Wells, J. D. & Kurahashi, H. (1994). *Chrysomya megacephala* (Fabricius) (Diptera: Calliphoridae) development: Rate, variation and the implications for forensic entomology. Japn. J. Sanitization Zool., 45: 303-309.

[92] Tantawi, T., El-kady, E. & Greenberg, B. (1996). Arthropod succession on exposed rabbit carrion in Alexandria, Egypt. J. Med. Entomol., 33 (4): 566-580.

[93] Thompson, F. C., Evenhuis, N. L. & Sabrosky, C. W. (1999). Bibliography of the Family-Group Names of Diptera, Pp. 361-556. In: Thompson F. C. (ed.). *Family-Group Names in Diptera and Bibliography*. MYIA Volume 10, Backhuys Publishers, North American Dipterists' Society, Leiden, Netherlands.

[94] Lindsay, S. W., Lindsay, T. C., Duprez, J., Hall, M. J. R., Kwambana, B. A., Jawara, M., Nurudeen, I. U., Sallah, N., Wyatt, N., D'Alessandro, U., Pinder, M. & Antonio, M. (2012). *Chrysomya putoria*, a Putative Vector of Diarrheal Diseases. PLoS Negl. Trop. Dis., 6 (11): e1895.

[95] Delabarde, T., Keyser C., Tracqui A., Charabidze D. & Ludes, B. (2013). The potential of forensic analysis on human bones found in riverine environment. Forensic Sci. Int., 228: e1-e5.

[96] Benecke, M., Ebehard, J. & Zweihoff, R. (2004). Neglect of the elderly: forensic entomology cases and considerations. Forensic Sci. Int. 146S: S195-S199.

[97] Hussein, S. A. & John, L. C. (2014). Housefly, *Musca domestica* Linnaeus (Insecta: Diptera: Muscidae). Inst. Food Agric. Sci., 47: 1-7.

[98] Ramaraj, P., Selvakumar, C., Ganesh, A. & Janarthanan, S. (2014). Report on the occurrence of synanthropic derived form of *Chrysomya megacephala* (Diptera: Calliphoridae) from Royapuram fishing harbour, Chennai, Tamil Nadu. Biodivers. Data J., 2: 1-12.

[99] Sukontason, K. L., Sanit, S., Klong-klaew, T., Tomberlin, J. K & Sukontasonm, K. (2014). *Sarcophaga (Liosarcophaga) dux* (Diptera: Sarcophagidae): A flesh fly species of medical importance. Biol. Res., 47: 14.

[100] Ommi, D., Hashemian, S. M., Tajbakhsh, E. & Khamesipour, F. (2015). Molecular detection and antimicrobial resistance of *Aeromonas* from houseflies (*Musca domestica*) in Iran. Revista MVZ Córdoba., 20 (Suppl): 4929-4936.

[101] Khamesipour, F., Lankarani, K. B., Honarvar, B. & Kwenti T. E. (2018). A systematic review of human pathogens carried by the housefly (*Musca domestica* L.). BMC Public Health, 18: 1049.

[102] Trout Fryxell, R. T., Moon, R. D., Boxler, D. J. & Watson, D. W. (2021). Face Fly (Diptera: Muscidae)—Biology, Pest Status, Current Management Prospects, and Research Needs. J. Integr. Pest Manag., 12 (1): 5; 1-18.

[103] ITIS (2022). *Muscina levida* (Harris, 1788). Integrated Taxonomic Information System. Anailable at www.itis.gov, CC0. Retrieved on June, 19, 2022.

[104] Biawa-Kagmegni, M., Foguieng-Saha, A. D., Guetsop-Ngouadjie, R. P., Tsekane, S. J., Fouelifack-Nintedem, B., Moumite-Mohamed, B., Yethom-Fondjo, J. A., Ngamaleu-Siewe, B., Kenne, E. L., Tuekam-Kowa, P. S., Fantio, R. M., Yomon, A. K., Mbenoun Masse, P. S., Kenne, M. & Fomena, A. (2021). Ants community structure in the urban and the city suburbs areas of Douala (Littoral-Cameroon). J. Insect Biodivers., 025 (2): 033–059.

[105] Moumite Mohamed, B., Tuekam-Kowa, P. S., Guetsop-Ngouadjie, R. P., Tsekane, S. J., Fouelifack-Nintidem, B., Biawa Kagmegni, M., Ngamaleu-Siewe, B., Kenne, E. L., Fantio, R. M., Yomon, A. K., Yetchom-Fondjo, J. A., Foguieng-Saha, A. D., Mbenoun Masse, P. S., Kenne, M. & Fomena, A. (2022). Nesting System and Foraging Behaviour of *Crematogaster (Nematocrema) stadelmanni* Mayr, 1895 (Hymenoptera: Formicidae: Myrmicinae) in Douala (Littoral-Cameroon). Am. J. Entomol., 6 (2): 27-42.

[106] Hammer, Ø., Harper, D. A. T. & Ryan, P. D. (2001). PAST: Paleontological Statistics software pakage for education and data analysis. Palaeontol. Electron., 4: 9.

[107] Margalef, R. (1978). Life forms of phytoplankton as survival alternatives in an unstable environment. Oceanol. Acta, 1 (4): 493-509.

[108] Krebs, C. J. (1999). *Ecologicam Methodoly*. Adison-Wesley Longman, USA, Canada, Pp. 620.

[109] Kikvidze, Z. & Oshawa, M. (2002). Measuring the number of co-dominants in ecological communities. Ecol. Res., 17: 519-525.

[110] Pielou, E. C. (1969). *An Introduction to Mathematical Ecology*. John-Wiley, New York, Pp. 294.

[111] Ludwig, J. A. & Raynolds, J. F. (1988). *Statistical Ecology*. John Wiley & Sons, New York, USA, Pp. 337.

[112] Cheng, C. C. (2004). Statistical Approches on Discriminating Spatial Variation in Species Diversity. Bot. Bull. Acad. Sin., 45: 339-346.

[113] Chao, A. & Jost, L. (2012). Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. Ecology, 93 (12): 2533-2547.

[114] Chao, A. (1984). Non-parametric estimation of the number of classes in a population. Scand. J. Stat., 11: 210-217.

[115] Chao, A., Chadzon, R. L., Colwel, R. K. & Shen, T. J. (2005). A new statistical approach for assessing similarity of species composition with incidence and abundance data. Ecol. Lett., 8: 148-159.

[116] Zipf, G. K. (1965). *Human Behaviour and thr Principle of Least Effort: An Introduction to human ecology*. 2nd edition, Hafner, New York, USA, Pp. 573.

[117] Iganaki, H. (1967). Mise au point de la loi de Motomura et essai d'une écologie évolutive. Vie Milieu, 18: 153-166.

[118] Daget, J. (1976). *Les modèles mathématiques en écologie.* Masson, Paris (France), Pp. 172.

[119] Frontier, S. (1987). Applications of Fractal Theory to Ecology, Pp. 335-378. In: Legendre P. & Legendre, L. (eds.). *Developments in Numerical Ecology.* NATO ASI book series (volume 14). Springer, Berlin, Heidelberg.

[120] Bach, P., Amanieu, M., Lam-Hoai, T. & Lassere, G. (1988). Application du modèle de distribution d'abondance de Mandelbrot à l'estimation des captures dans l'étang de Thau. J. Cons. Int. Explor. Mer., 44: 235-246.

[121] Galante, E. & Cartagena, M. C. (1999). Comparison of Mediterranean dung beetles (Coleoptera: Scarabaeoidea) in cattle and rabbit dung. Environ. Entomol., 28 (3): 420-424.

[122] McGill, B. J., Etienne, R. S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., Dornelas, M., Enquist, B. J., Green, J. L., He, F., Hurlbet, A. H., Magurran, A. E., Marquet, P. A., Maurer, B. A., Ostling, A., Soykan, C. U., Ugland, K. I. & White, E. P. (2007). Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. Ecol. Lett., 10 (10): 995-1015.

[123] Ferreira, F. C. & Petrere-Jr., M. (2008). Comments about some species abundance patterns: classic, neutral, and niche partitioning models. Braz. J. Biol., 68 (4, Suppl.): 1003-1012.

[124] Li, W. (2002). Zipf's Law Everywhere. Glottometrics, 5: 14-21.

[125] Wilson, J. B. (1991). Methods for fitting dominance/diversity curves. J. Veg. Sci., 2 (1): 35-46.

[126] Johnson, J. B., & Omland, K. S. (2004). Model selection in ecology and evolution. Trends Ecol. Evol., 19 (2): 101-108.

[127] R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/. Assessed on 10th Jun 2022.

[128] Sukontason, K. L., Bhoopat, T., Wannasan, A., Sontigun, N., Sanit, S., Amendt, J., Samerjai, C. & Sukontason, K. (2018). *Chrysomya chani* Kurahashi (Diptera: Calliphoridae), a blow fly species of forensic importance: morphological characters of the third larval instar and a case report from Thailand. Forensic Sci. Res., *3* (1), 83-93.

[129] Whitworth, T. L., Bolek, M. G. & Arias-Robledo, G. (2021). *Lucilia bufonivora*, Not *Lucilia silvarum* (Diptera: Calliphoridae), Causes Myiasis in Anurans in North America With Notes About *Lucilia elongata* and *Lucilia thatuna.* J. Med. Entomol.*,* 58 (1): 88-92.

[130] Siwel, O. (2018). *Phormia regina* (Meigen) (Diptera, Calliphoridae) in Britain. Dipterists Digest., 25: 113-118.

[131] Rueda, L. C., Ortega, L. G., Segura, N. A., Acero, V. M. & Bello, F. (2010). Lucilia sericata strain from Colombia: Experimental colonization, life tables and evaluation of two artificial diets of the blowfly Lucilia sericata (Meigen) (Diptera: Calliphoridae), Bogota, Colombia strain. Biol. Res., 43: 197-203.

[132] Szpila, K., Hall, M. J. R., Pape, T. & Grzywacz, A. (2012). Morphology and identification of first instars of the European and Mediterranean blowflies of forensic importance. Part II. Luciliinae. Med. Vet. Entomol., 27 (4): 349-366.

[133] Arias-Robledo, G., Stark, T., Wall, R. L. & Stevens, J. R. (2019). The toad fly *Lucilia bufonivora*: its evolutionary status and molecular identification. Med. Vet. Entomol., 33 (1): 131-139.

[134] Cook, D. F., Voss, S. C, Finch., J. T. D., Rader, R. C., Cook, J. M. & Spurr, C. J. (2020). The Role of Flies as Pollinators of Horticultural Crops: An Australian Case Study with Worldwide Relevance. Insects, 11 (6): 341.

[135] Gruner, S. V., Slone, D. H. & Capinera, J. L. (2007). Forensically Important Calliphoridae (Diptera) Associated with Pig Carrion in Rural North-Central Florida. J. Med. Entomol., 44 (3): 509-515.

[136] Andrade-Herrera, K., Núñez-Vázquez, C. & Estrella, E. (2021). Life Cycle of *Chrysomya rufifacies* (Diptera: Calliphoridae) Under Semi-Controlled Laboratory Conditions. J. Med. Entomol., 58 (6): 2138-2145.

[137] Sukontason, K., Sukontason, K., Narongchai, P., Lertthamnongtham, S., Piangjai, S. & Olson, J. K. (2021). *Chrysomya rufifacies* (Macquart) as a forensically-important fly species in Thailand: a case report. J. Vector Ecol., 26: 162-164.

[138] Boulesteix, G., Le Dantec, P., Chevalier, B., Dieng, M., Niang, B. & Diatta, B. (2005). Rôle de Musca domestica dans la transmission des bactéries multirésistantes dans un service de réanimation en Afrique subsaharienne. Ann. Fr. Anesth. Reanim., 24 (4): 361-365.

[139] Nassiri, H., Zarrin, M., Veys-Behbahani, R., Faramarzi, S. & Nasiri, A. (2015). Isolation and identification of pathogenic filamentous fungi and yeasts from adult house fly (Diptera: Muscidae) captured from the hospital environments in Alivaz city, Southwestern Iran. J. Med. Entomol., 52 (6): 1351-1356.

[140] Tsagaan, A., Kanuka, I. & Okado, K. (2015). Study of pathogenic bacteria detected in fly samples using universal primer-multiplex PCR. Mong. J. Agric. Sci., 15 (2): 27-32.

[141] Benecke, M. (1998). Six forensic entomology cases: description and commentary. J. Forensic Sci., 43 797-805.

[142] Gunn, A. (2016). The colonisation of remains by the muscid flies *Muscina stabulans* (Fallén) and *Muscina prolapsa* (Harris) (Diptera: Muscidae). Forensic Sci. Int., 266: 349-356.

[143] Grisales, D., Ruiz, M. & Villegas, S. (2010). Insects associated with exposed decomposing bodies in the Colombian Andean Coffee Region. Rev. Bras. Entomol., 54: 637-644.

[144] Badenhorst, R. & Villet, M. H. (2018). The uses of Chrysomya megacephala (Fabricius, 1794) (Diptera: Calliphoridae) in forensic entomology. Forensic Sci. Res., 3. 1-14.

[145] Grzywacz, A., Jarmusz, M. & Szpila, K. (2018). New and noteworthy records of carrion-visiting *Fannia* Robineau-Desvoidy (Diptera: Fanniidae) of Poland. Entomol. Fenn., 29 (4): 169-174.

[146] Duarte, J. L. P., Krüger, R. F. & Ribeiro, P. B. (2013). Interaction between Musca domestica L. and its predator Muscina stabulans (Fallén) (Diptera, Muscidae): effects of prey density and food source abundance. Rev. Bras. Entomol., 57: 55-58.

[147] Barker, G. M. (2004). *Natural ennemies of terestrial Molluscs*. CABI International, Wallingford, Oxfordshire, UK, Pp. 644.

[148] Cherix, D., Wyss, C. & Pape, T. (2012). Occurrences of flesh flies (Diptera: Sarcophagidae) on human cadavers in Switzerland, and their importance as forensic indicators. Forensic Sci. Int., 220: 1-3.

[149] Fremdt, H. & Amendt, J. (2014). Species composition of forensically important blow flies (Diptera: Calliphoridae) and flesh flies (Diptera: Sarcophagidae) through space and time. Forensic Sci. Int., 236: 1-9.

[150] Szpila, K., Madra, A, Jarmusz, M., Matuszewski, S. (2015). Flesh flies (Diptera: Sarcophagidae) colonising large carcasses in central Europe. Parasitol. Res., 114: 2341-2348.

[151] Matuszewski, S., Fratczak, K., Konwerski, S., Bajerlein, D., Szpila, K., Jarmusz, M., Szafałowicz, M., Grzywacz, A. & Mądra, A. (2016). Effect of body mass and clothing on carrion entomofauna. Int. J. Legal Med., 130: 221-232.

[152] Holway, D. A., Lach, L., Suarez, A. V., Tsutsui, N. D., & Case, T. J. (2002). The causes and components of ant invasions. Annu. Rev. Ecol. Syst., 33: 181-233.

[153] Wheeler, Jr. A. G. & Hoebeke, E. R. (2017). Adventive (Non-Native) Insects and the Consequences for Science and Society of Species that Become Invasive, Pp. 641-711. In: Foottit, R. G. & Adler, P. H. (eds.). *Insect Biodiversity: Science and Society, Volume I*, Second Edition. John Wiley & Sons Ltd, USA.

[154] Murillo, A. C., Hubbard C. B., Hinkle N. C. & Gerry, A. C. (2021). Big Problems With Little House Fly (Diptera: Fanniidae). J. Integr. Pest Manag., 12. 10.1093/jipm/pmaa023.

[155] Fetene, T. & Worku, N. (2008). Public health importance of non-biting cyclorrhaphan flies. Trans. R. Soc. Trop. Med. Hyg., 103. 187-91.

[156] Khoso, F. N., Wong, S. K., Chia, S. L. & Lau, W. H. (2015). Assessment of non-biting synanthropic flies associated with fresh markets. J. Ent. Zool. Stud., 3: 13-20.

[157] Khofar, P. N., Kurahashi, H., Zainal, N. S., Isa, M. S. & Heo, C. C. (2019). Diversity of Coprophilic Diptera associated with buffalo dung in Selangor, Malaysia. J. Wildl. Parks, 34: 63-80.

[158] Courtney, G. W., Pape, T., Skevington, J. H. & Sinclair, B. I. (2017). Biodiversity of Diptera, Pp. 229-278. In: Foottit R. G. & Adler P. H. (eds.). Insect Biodiversity: Science and Society, Volume I, Second Edition. John Wiley & Sons Ltd, USA.

[159] Carpentier, P. & Leprêtre, A. (1999). Robustesse de quelques indices de diversité à l'échantillon. Océanis, 25 (3): 435-455.

[160] Trouillet, J. & Vattier-Bernard, G. (1983). Phlébotomes du Mayombe Congolais (Diptera, Psychodidae). Analyse structurale de trois peuplements. Ann. Parasitol. Hum. Comp., 58 (3): 291-300.

[161] Komonen, A. & Elo, M. (2017). Ecological response hides behind the species abundance distribution: Community response to low-intensity disturbance in managed grasslands. Ecol. Evol., 7: 8558-8566.

[162] Fouelifack-Nintidem, B., Yetchom-Fondjo, J. A., Tsekane, S. J., Ngamaleu-Siewe, B., Kenne, E. L., Biawa-Kagmegni, M., Tuekam-Kowa, P. S., Yomon, A. K., Kentsop-Tsafong, R. M., Dim-Mbianda, A. M. & Kenne, M. (2021). Diversity and abundance of pest insects associated with the Ethiopian eggplant plants *Solanum aethiopicum* Linnaeus, 1756 (Solanaceae) in Balessing (West-Cameroon). Am. J. Entomol., 5 (3): 70-91.

[163] Ngamaleu-Séwé, B., Fouelifack-Nintidem, B., Yetchom-Fondjo, J. A., Moumite Mohamed, B., Tsekane, S. J., Kenne, E. L., Biawa-Kagmegni, M., Tuekam Kowa, P. S., Fantio, R. M., Yomon, A. K. & Kenne, M. (2021). Abundance and diversity of insects associated with *Solanum tuberosum* L. 1753 (Solanaceae) after insecticide treatments in Balessing (West-Cameroon). Am. J. Entomol., 5 (3): 51-69.

[164] Yetchom-Fondjo, J. A., Kekeunou, S., Kenne, M., Missoup, A. D., & Sheng-Quan, X. (2020). Diversity, abundance and distribution of grasshopper species (Orthoptera: Acrididea) in three different types of vegetation with different levels of anthropogenic disturbances in the Littoral Region of Cameroon. J. Insect Biodivers., 14 (1): 16-33.

[165] Béguinot, J. (2018). Analysing the Role of Environmental Stresses on Species Richness and the Process of Hierarchical Structuring of Species Abundances in Marine Gastropods communities at Suva (Fiji Islands). Int. J. Environ., 8 (3): 200-233.

[166] Kunakh, O. & Kovalenko, D. (2019). Fitting Competing Models of the Population Abundance Distribution: Land Snails from Nikopol Manganese Ore basin Technosols. Ekol. Bratisl., 38 (4): 367–381.

[167] Kenne, E. L., Yetchom-Fondjo, J. A., Moumite-Mohamed, B., Tsekane, S. J., Ngamaleu-Siewe, B., Fouelifack-Nintidem, B., Biawa-Kagmegni, M., Tuekam-Kowa, P. S., Fantio, R. M., Kayoum-Yomon, A., Kentsop-Tsafong, R. M., Dim-Mbianda, A. M. & Kenne, M. (2021). Species composition and diversity of freshwater snails and land snails at the swampy areas and streams edges in the urban zone of Douala, Cameroon. Int. J. Biol. Chem. Sci., 15 (4): 1297-1324.

[168] Errouissi, F., Jay-Robert, P., Lumaret, J.-P. & Piau, A. (2004). Composition and Structure of Dung Beetle (Coleoptera: Aphodiidae, Geotrupidae, Scarabaeidae) Assemblages in Mountain Grasslands of the Southern Alps. Ann. Entomol. Soc. Am., 97 (4): 701-709.

[169] McDonald, R. I., Marcotullio, P. J. & Güneralp, B. (2013). Urbanization and Global Trends in Biodiversity and Ecosystem Services, In Pp. 31-52. In: Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P. J., McDonald, R. I., Parnell, S., Schewenius, M., Sendstad, M., Seto, K. C., Wilkinson, C. (eds.). *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. A Global Assessment. A Part of the Cities and Biodiversity Outlook Project.* The Netherlands: Springer Open, Springer, Dordrecht, Heidelberg, New York, London.