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Spatio-Temporal Distribution of Sciomyzidae (Diptera) in Relation to Environmental Characteristics in Four Localities of Benin, West Africa

AGBOHO A. Prudenciène[1*], GBEDJISSI Ghélus[2], AHOGNI Idelphonse[3], JAY- ROBERT Pierre[4], AKOGBETO C. Martin[5], and VALA J. Claude[6]

[1, 2, 3, 4]Département de Zoologie, Laboratoire Evolution, Biodiversité des Arthropodes et Assainissement, FAST; BP 823 Cotonou; Benin

[5]Département de Biologie-Ecologie et Environnement : CEFE UMR 5175, CNRS - Université Paul-Valéry Montpellier, route de Mende 34199 Montpellier cedex 5. France

[6]Université d'Orléans. UFR sciences. Laboratoire de Biologie des Ligneux et des Grandes Cultures, UPRES EA 1207, BP 6759 –45067 Orléans cedex 2 (France)

*Corresponding Author E-mail: aprudencine@yahoo.com

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ABSTRACT

This study establishes the spatio-temporal distribution of Sciomyzidae (Diptera) in relation with environmental factors in four localities in Benin. These communities are located at the south (localities 1 and 2) and at the center (localities 3 and 4) and were sampled monthly during an annual cycle from August 2014 to July 2015. The test of Shapiro, of Kruskal Wallis, the Analysis in Principal Component (ACP) and the Factorial Analysis of Correspondences (AFC) were applied to all the data obtained. A total, eight species were identified with an abundance 3656 individuals enumerated throughout the study period. Sepedon (Parasepedon) ruficeps and Sepedon (Parasepedon) trichrooscelis dominated all the stands. The variation of abundance, temperature and rainfall is highly significant from one locality to another and season to another (p <0.001). The typologies realized by the ACP and AFC reveal two opposite groups, GI and GII, characterized by an equidistant distribution of the species.

Key words: *Sciomyzidae species, Dynamic population, Diversity indices, Afrotropical region.*

INTRODUCTION

The protection of Human against vector-borne diseases has always been the main concern of humanity. Among strategies for combating diseases, the vector control seems the main tool despite its little successfulness. The origin of this failure is often related to insufficient knowledge of the ecology of vectors, its predator and its environment, or an inadequate control strategy. The Sciomyzidae (Diptera) whose larvae are predators of intermediate snail hosts of Schistosomiasis and fascioliasis include 540 species of 61 genera in the world[9] and the Afrotropical fauna, which has 62 species. The knowledge of the biology and ecology of Sciomyzids is known only for species of Palearctic, Nearctic and Neotropical regions[1, 21, 5] regions.

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Schistosomiasis, found in the tropics is responsible for about 207 million people[17, 7] and the control methods used for its eradication are more chemical and biological. They are based on the combination of chemical control of molluscs and chemotherapy, the disadvantages of which are enormous[10, 11]. Regarding the high prevalence rates of the disease, few control actions have been initiated due to a lack of knowledge of the mollusc predator species and their ecology. The study of population dynamics in Sciomyzidae is useful to apprehend the quantitative and qualitative importance of adults, their spatial location and their seasonal variations. It is also necessary to assess the impact of these diptera on mollusc-prey stands. It makes it possible to determine the environmental factors that control the periodic fluctuations observed in the populations studied.

The present study aims to describe the population dynamics of Sciomyzidae in relation to environmental variables in four localities in Benin.

MATERIALS AND METHODS

Study Area

In Benin located between latitude 6° 15' and 12° 25' north and between longitude 0° 45' and 4° 00' east, the present study was carried out in the meridional part from August 2014 to July 2015. Samplings were done in eight stations composed of 4 permanent water environments and 4 temporary water environments regularly surveyed every fortnight. Stations are divided into two parts: Cocotomey-Pahou (Locality 1), Djeffa-Accron (Locality 2), Za-zounmè-Djidja (Locality 3) and Dah-Daho-Wlé-Wlé (Locality 4). The prospected ecosystems were dominated by the common marsh plants like *Paspalum vaginatum* (Poaceae), *Leersia hexandra* (Poaceae), *Cyperus articulatus* (Cyperaceae). *Cyperus articulatus* (Cyperaceae), *Pentodon pentandrus* (Rubiaceae), *Jussiea sp* (Onagraceae), *Diplazium sammatii* (Athyriaceae), *Thalia welwitchii* (Araceae) *Ipomea aquatica* (convolvulaceae) and *Ludwigia abyssinica* (Onagraceae). The geographical informations were collected using a Global Position System (GPS). The geographical location of study sites is given in Figure 1. Localities and their geographical coordinates are presented in Table 1

Table 1: Geographical positioning of the localities

Codes	Stations	environment	Geographic coordinates
	Cocotomey	Temporary	2°26'E ; 6°21'N
Loc1	Pahou	Permanent	2°12'E ; 6°37'N
	Djeffa	Temporary	2°36'E ; 6°23'N
Loc2	Accron	Permanent	2°42'E ; 6°27'N
	Za-zounmè	Temporary	2°13'E ; 7°13'N
Loc3	Djidja	Permanent	1°55'E ; 7°21'N
Loc4	Dah-Daho	Temporary	2°17'E ; 7°45'N
	Wlé-Wlé	Permanent	2°19'E ; 7°46'N

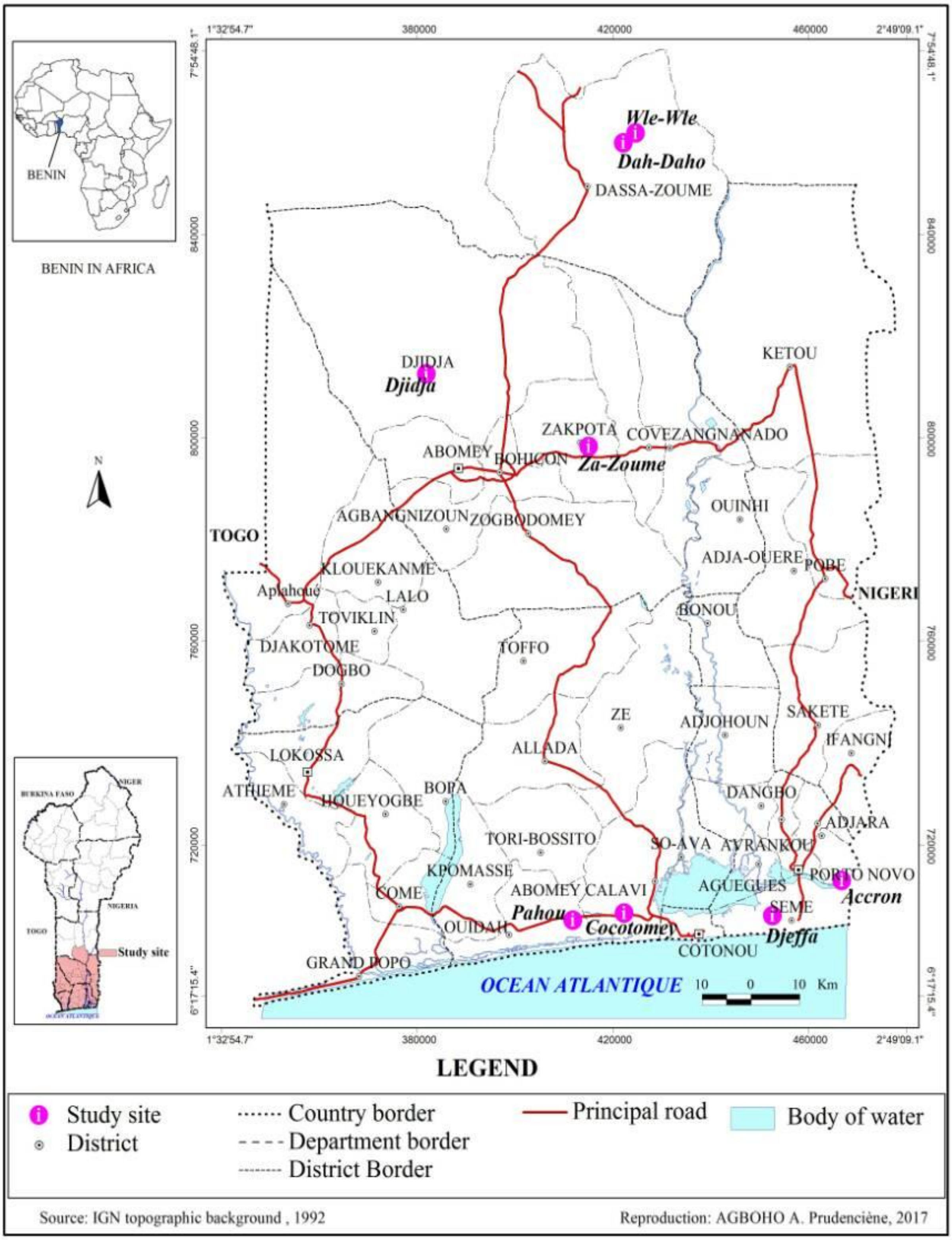

Fig. 1: Study area

Sciomyzidae sampling, identification and conservation

Adults flies were caught two times a month with a traditional sweeping net during three times of 30 minutes each at 7h; 13h; 18h from different sites and then transferred to a traditional mouth vacuum cleaner through a traditional mouth aspirator. After summary identification and enumeration, all individuals are immediately released so as not to alter the numerical relationship between the species except for 2 to 3 pairs kept for laboratory breeding and for the study of spawning and staging larval. The morphological identification of the adults caught was carried out under a binocular microscope or under a microscope on essential characteristics of morphology concerning the general cholotaxy, the coloring, the postabdomen of the males mounted in a drop of glycerin. For each species of Sciomyzidae identified, the number of adults caught per fortnight, by locality, for each catch survey was reported in a table. After identification, the adults are preserved in alcohol 70 °, 95 °.

Measurement of environmental characteristics

Assessing of the influence of ambient temperature, relative humidity and precipitation on the fluctuation of sciomyzids population, measurements of the factors above were collected from the registration site of ASECNA (Agency for Aerial Navigation Safety in Africa and Madagascar) of Cotonou for each locality.

Data analysis

Specific richness, Shannon indices and evenness were used to determine the structure and dynamics of the population of Sciomyzidae. Standard methods were followed to estimate different diversity indices. The Shannon-Weaver index (H') expressed in individual bits-1 was evaluated following the formula:

$$\mathbf{H' = -\sum_{i=1}^{S} \frac{Ni}{N} Log \frac{Ni}{N}}$$

H': Shannon index (bits); Ni: Number of species i and N: Total number of individuals.

Whereas index of evenness (E) Pielou[15] is calculated using the formula:

$$\mathbf{E = H'/log_2 S}$$

H: Index of specific diversity of Shannon and Weaver; Log2 S = Hmax; S, number of species in the sample.

The occurrence (F) providing information on the station preferences of a given species it was calculated according[3].

F = (Fi * 100) / Ft with Fi = Number of readings containing the species i; Ft = Total number of surveys performed. Depending on the value of the occurrence percentage F, the species are classified into three groups: constant species with F ≥ 50%; Accessory species if 25% ≤ F<50% and accidental species if F<25%.

The most commonly used are those of Shannon-Weaver and Pielou's equitability[3] that perfectly account for the state of ecosystems.

Statistical analysis

The Shapiro-Wilk test was applied to check whether the values of the different measured parameters follow a normal distribution. The Kruskal-Wallis test was used to test the variability of abundances, rainfall and temperature according to the months and the defined localities. For the establishment of both biotic and abiotic typology of the species, a Principal Component Analysis (PCA) and a Factor Analysis of Correspondence (CFA) were applied respectively for the factorial map of the localities and the distribution of the species in the localities studied. All the statistical analysis was carried out with the R Version 2.15.3 provided with the package FactoMineR software.

RESULTS

Qualitative analysis of the entomofaune of Sciomyzidae

During the study period, eight species of Sciomyzid distributed in three genera were identified (Table 2). There are *Sepedon* (*Mesosepedon*) *knutsoni*, *Sepedon (Parasepedon) straeleni, Sepedon (P) trichrooscelis, Sepedon (P) umbrosa, Sepedon (P) ruficeps, Sepedon (Sepedomyia) nasuta, Sepedonella nana* and *Sepedoninus curviseti*s. This collect showed that the genus *Sepedon* is more present in these localities than the other genera *Sepedonella* and *Sepedoninus.* Noted that *Sepedon (P). straeleni* and *S. (S). nasuta* are recorded for the first time in Benin. Their occurrence in different localities is presented in table 2. Figure 2 showed that species richness varies between localities and the specific abundance of Sciomyzidae is 4 and 6 species for localities 1 and 3, respectively, whereas it is of 2 and 3 species for the localities 2 and 4 respectively.

Table 2: List and numbers of species in different localities during the study

Species	Loc1	Loc2	Loc3	Loc4	Occurrence %
Sepedon(P).ruficeps	432	502	407	293	**87, 12**
Sepedon (P) trichrooscelis	300	320	267	337	**65,13**
Sepedon(P). umbrosa	168	0	0	0	**17,45**
Sepedon (P).straeleni*	0	0	6	0	**9,15**
Sepedon (P).knutsoni	0	0	65	0	**19,13**
Sepedon (M).nasuta*	0	0	0	121	**27,06**
Sepedonella nana	137	0	139	0	**24,21**
Sepedoninus curvisetis*	0	0	162	0	**29,45**

(*: Species cited for the first time in Benin)

Figure 2 shows the specific richness in the different localities and the type of environment.

According to the environment, localities 1 and 4 contain the same number of species caught as a function of the temporary or permanent environment. However, in locality 1, we have *Sepedon (P) umbrosa* and in locality 4, *Sepedon (Sepedomyia) nasuta*. In locality 2, the two types of environment contain the same number of species *Sepedon (P), ruficeps*, and *Sepedon (P) trichrooscelis*. The large increase in the number of species caught in locality 3 composed of the Djidja and Za-zounmè stations and the evolution of the catches in the temporary environment are almost parallel to that of the permanent environment, with a very low catch rate for *Sepedon (P) straeleni* in temporary environment.

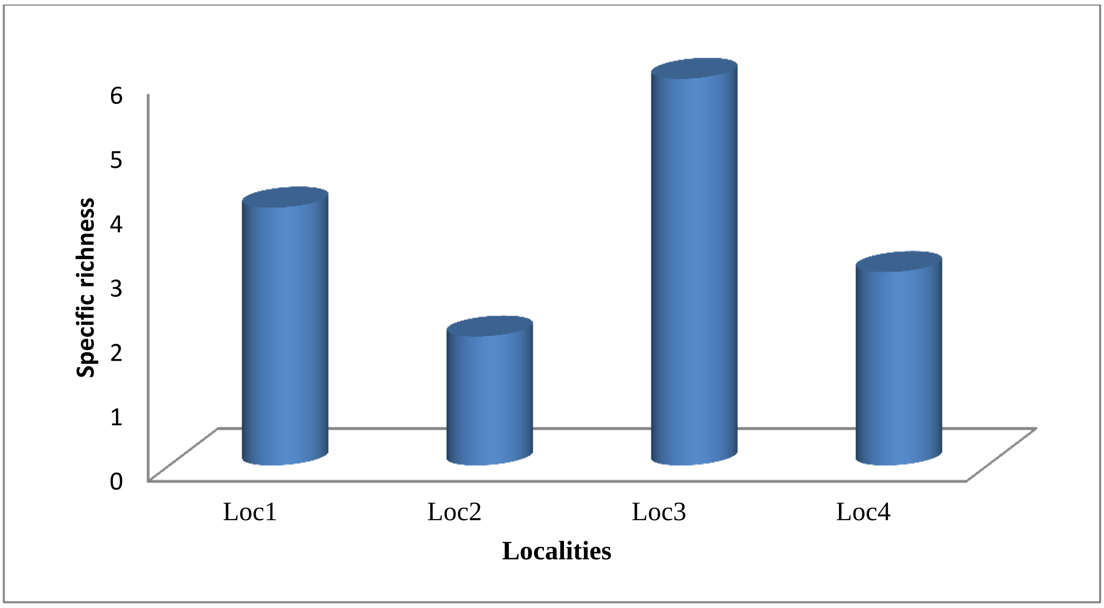

Fig. 2: Species richness of different localities

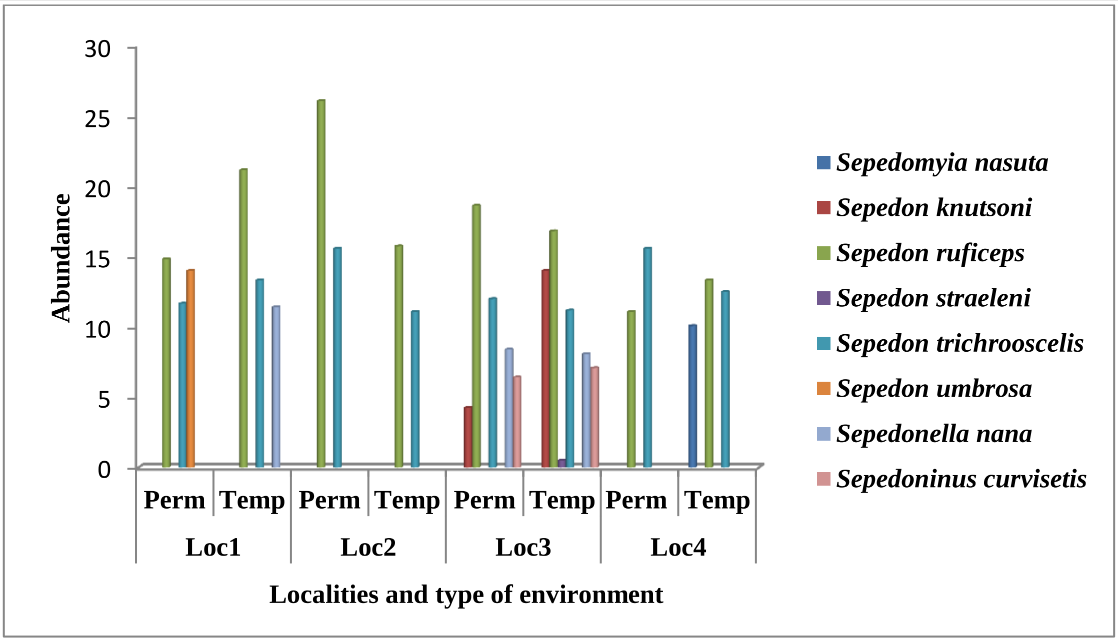

Fig. 3: Distribution of Sciomyzidae captured by type of environment

Hierarchical classification

According to the relative abundance and frequency, the species collected are distributed in Table 3. In eight species, two are constants. These are *Sepedon (P) ruficeps and Sepedon (P) trichrooscelis*, which are 87.12% and 65.13% of the total number of individuals respectively.

Table 3: Hierarchical classification of species

Constant species (F≥50%)	Accessory species (25<F<50%)	Accidental species (F≤25)
Sepedon (P) ruficeps		*Sepedomyia (S) nasuta*
Sepedon (P) trichrooscelis		*Sepedon (M) knutsoni*
		Sepedon(P) umbrosa
		Sepedonella nana
		Sepedoninus curvisetis
		Sepedon (P) straeleni

Quantitative analysis of entomofauna

Specific diversity

Abundance varies in the same sense as the specific richness. In localities, the relative abundance of species varies widely. A total of 3656 individuals were caught during the study period in all the study sites. The localities 1 and 3 respectively contain 1037 and 1046 individuals; Then locality 2 with 822 individuals and finally locality 4 with 751 individuals (Figure 3). The highest average abundance was recorded in locality 3 (Djidja and Za-zounmè).

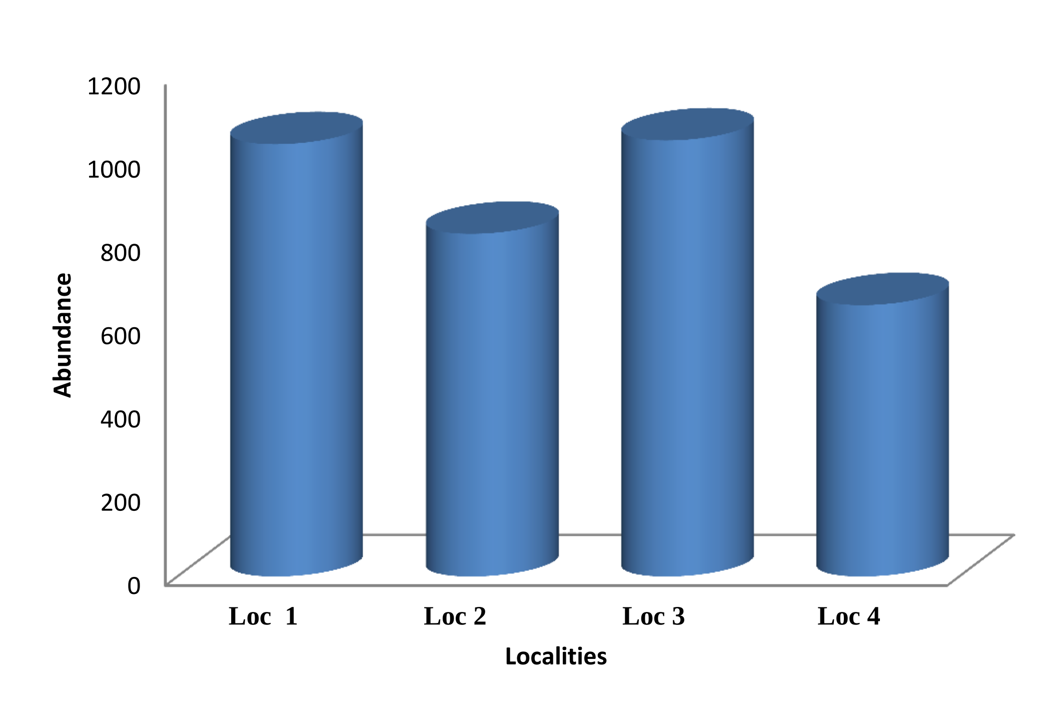

Fig. 4: Total abundance of Sciomyzidae in the four sampled locations.

Indices of diversity

The analysis of the specific diversity of the different localities showed high values of the Shannon-Weaver (H ') and Pielou evenness index (Table 4). The most important values of Shannon (3.91, 4.12) were recorded at locations 1 and 3, while the minimum values (3.50, 3.56) were observed at localities 2 and 4. The same holds for fairness (0.79, 0.75) and (0.69; 0.74).

Table 4: Shannon Index Values and Pielou's Index of Species Evenness

Localities	Specific richness (%)	Abundance (Number of individuals)	Shannon index H'	Pielou's Index E
Loc. 1	4	1037	3,91	0,79
Loc. 2	2	822	3,50	0,69
Loc. 3	6	1046	4,12	0,75
Loc. 4	3	751	3,56	0,74

Spatio-temporal variations in abundance of sciomyzids as a function of abiotic factors

Global evolution of annual seasonal Sciomyzidae are followed stands in all localities. The variation in species abundance as a function of temperature and rainfall of the sampling locations is shown in (Figure 5). The analysis shows that locations 1 and 2 are marked by low rainfall values except for June with a high peak corresponding to the great rainy season. Correlatively, there is a low abundance of species probably induced by this peak of rainfall. In all localities, the number of individuals is high from July to November and the minimum values are met during the months of December to June. This is due to the fact that during these months abiotic factors have favored the absence of the species. Temperature and rainfall are therefore determining factors for the presence of Sciomyzids. The results of the Kruskal-Wallis comparison tests show that they are abiotic or biotic, all the parameters measured (species abundance, temperature and rainfall of sampling locations) vary with a highly significant probability (P <0.001) from one month to another and from one locality to another (Table 5).

In summary, our results show that the seasonal variation of species is unstable and

Sciomyzidae species occur only at a time of year: June to December. A high catch rate was noted during August in most localities and a gradual decrease in abundance from August to February was observed. We can then conclude that seasonal variations influence the structure of populations of sciomyzidae.

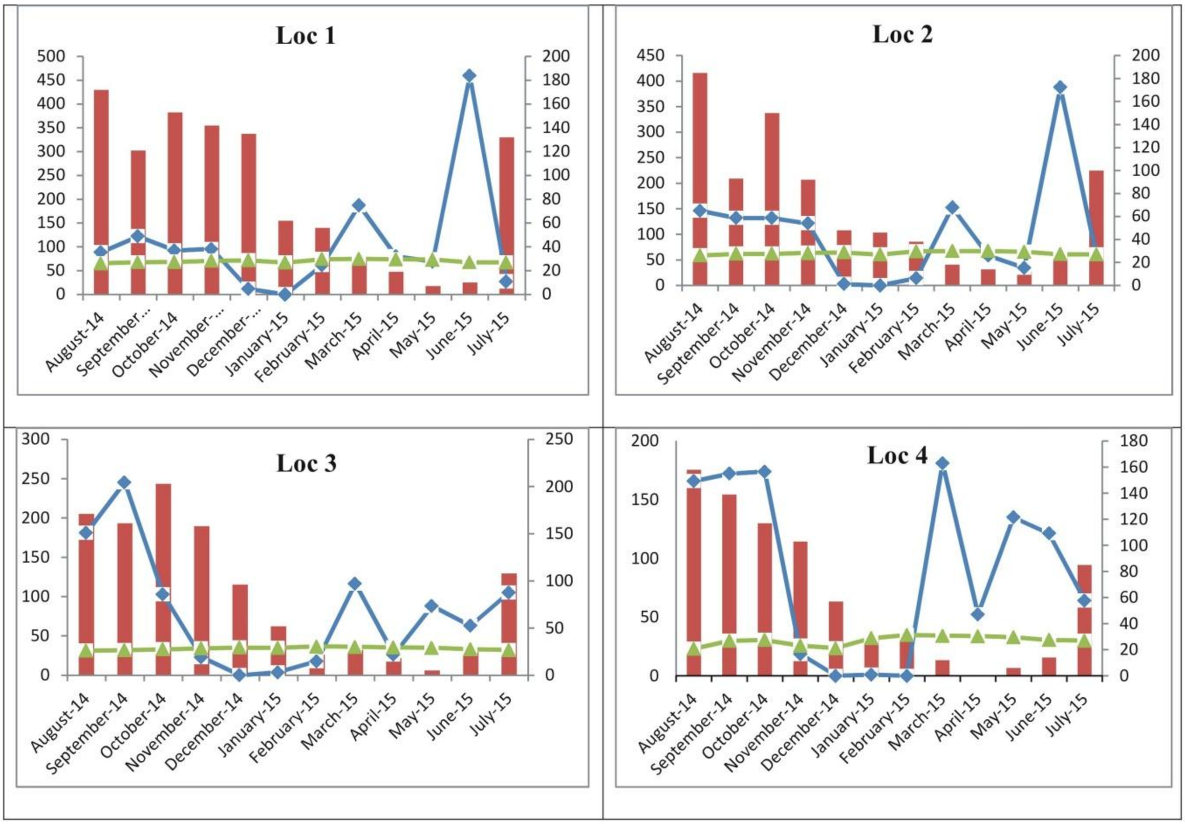

Fig. 5: Species dynamics according to the different temperature and rainfall variations in the different localities

Table 5: Summary of the results of the Kruskal-Wallis comparison tests on seasonal parameters variations (species abundance, rainfall and temperature) of the different localities

Localities	Parameters	Kruskal-test	P values	Significance
	Abundance	56,22	4,621e-08	***
	Rainfull	66,53	5,555e-10	***
Loc1	Temperature	70,87	8,324e-11	***
	Abundance	39,8916	3,733e-05	***
	Rainfull	47	2,151e-06	***
Loc2	Temperature	47	2,151e-06	***
	Abundance	59,1873	1,312e-08	***
	Rainfull	110,8084	< 2,2e-16	***
Loc3	Temperature	110,8084	< 2,2e-16	***
	Abundance	44,4078	6,165e-06	***
	Rainfull	58,3758	1,854e-08	***
Loc4	Temperature	58,3758	1,483e-08	***

***: Highly significant

Abiotic and biotic typology

Between the Main Component Analysis and the environmental variables in the different localities, two groups were formed (Figure 6). The first group consists mainly of localities 1 and 3 whose specific richness and Shannon index are high compared to second group composed of localities 2 and 4 with low values of specific richness and Shannon index. The localities of group I are positively correlated to axis 1 which contains 74.59% of the total information whereas the negative part of this axis groups together the localities of group 2 (15.08%). This clearly indicates the opposition of group I to group II.

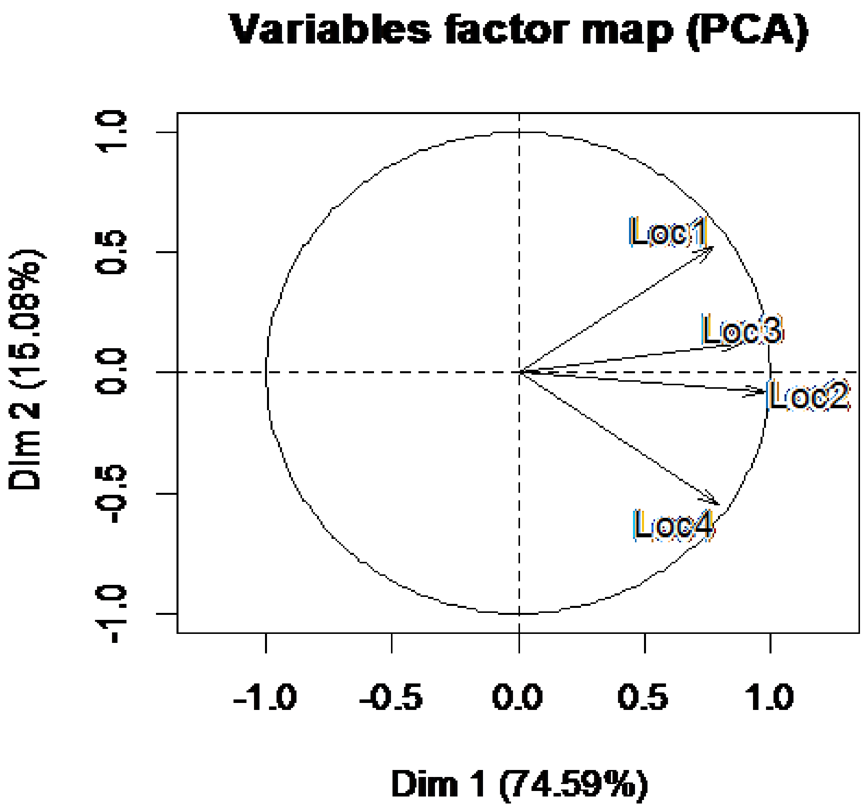

Fig. 6: Principal Component Analysis based on the temperature and rainfall of the localities

The result of the Factor Analysis of Matches based on the mean values of the abundances of the species of the groups obtained after the principal component analysis reveals that the first two axes concentrate 84.72% of the initial information, which is sufficient to ensure accurate interpretation (Figure 7). These two axes were considered for the ordination of the samples. Thus, the highest abundances of *Sepedon (P) straeleni*, *Sepedon (M) knutsoni* and *Sepedoninus curvisetis* are positively correlated with axis 2 and are opposed to the low abundances of the species *Sepedonella nana* and *Sepedon (P) umbrosa*. As for the species *Sepedon (P) trichrooscelis*, it is found to be negatively correlated is axis 1. It emerges from this analysis that the substantial part of the taxa harvested is in localities 2, 3 and 4.

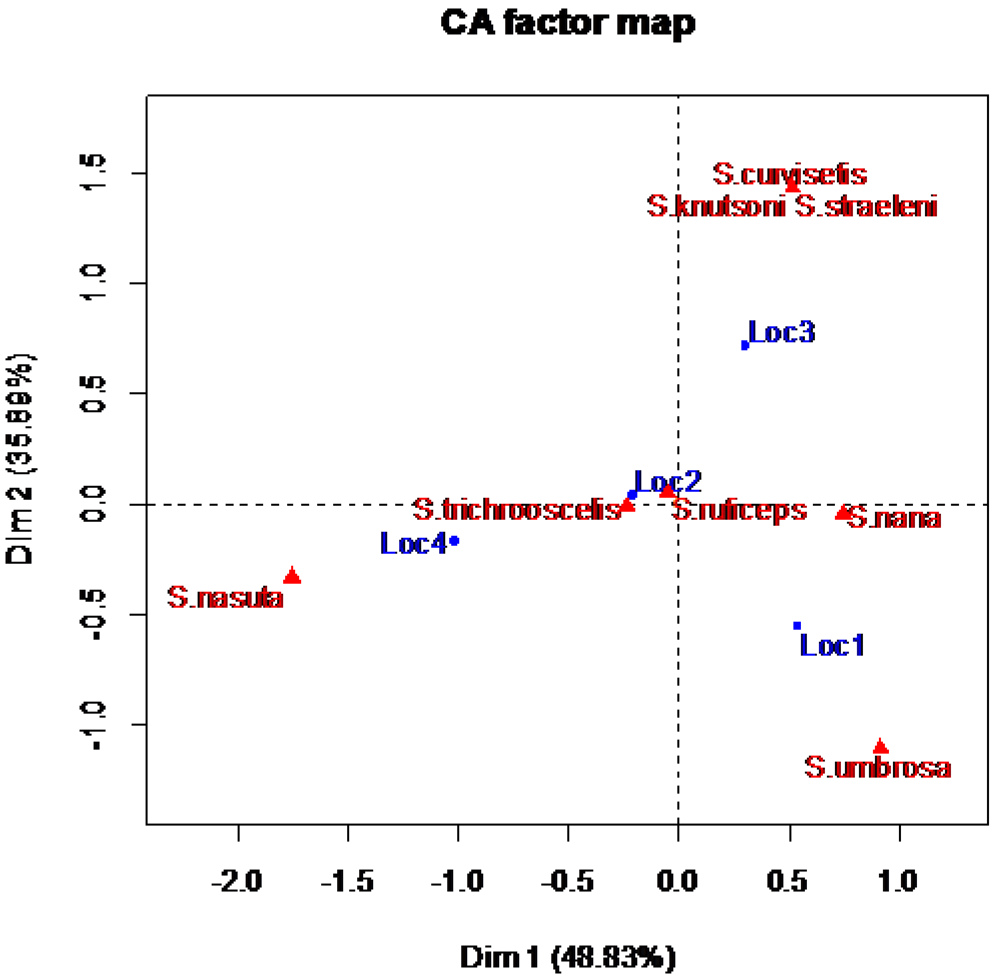

Fig. 7: Factorial Correspondence Analysis based on the abundance of species

DISCUSSION

This study, which shows the presence of eight Sciomyzidae species in four localities in Benin, was carried out in Za-zounmè-Djidja (Locality 3) and Dah-Daho-Wlé-Wlé (locality 4). Among these species, six (*Sepedon (M) knutsoni*, *Sepedon (P) straeleni*, *Sepedon (P) trichrooscelis*, *Sepedon (P) umbrosa*, *Sepedon (P) ruficeps and Sepedonella nana*) have already been reported in Benin (Vala et al. 1994) and the genus *Sepedon* has been reported to be the most widespread in the afrotropical region[22]. The fauna diversity in locations 3 and 4 that have never been exploited offers a variety of species of Sciomyzidae, which explains this high species richness with the presence of three new species *Sepedoninus curvisetis*, *Sepedon (P) straeleni* (locality 3) and *Sepedon (Sepedomyia) nasuta* (locality 4).

These species have not been observed in other localities and the low diversity of Sciomyzidae in localities 1 and 2 could be explained by human action (Gbedjissi, 2003). *Sepedon (P) ruficeps and Sepedon (P) trichrooscelis* are the dominant species in the various localities. This dominance would be favored by the ecology and diet of their larvae[9]. These sciomyzidae frequent and colonize permanent, temporary or simply humid aquatic environments and the period of activity of adult sciomyzids covers the whole year[5,9]. Numerous factors can explain variation of insect population. The development of populations of Sciomyzidae species depends on the conditions of the environment (temperature and rainfall), the availability of resources (host molluscs) and their suitability for species needs.

Large-scale prospecting for longer periods will allow us to better appreciate the diversity of Sciomyzidae. The abundance of *Sepedon* (*P) ruficeps* and *Sepedon (P) trichrooscelis*, whose larvae are predators and parasitoids of molluscs, intermediate hosts of schistosomiasis in the localities studied, their high reproductive capacity and their adaptation to environmental conditions are favorable to the development of their population, hence their abundance in catches[6,20]. Thus, there are species both subspecies at a single station and species common to all four. Indeed, some authors[2, 12, 14] attribute the weak similarities of study stations to well-defined factors: bioclimatic which may be different, exposure, altitude and the structure of the vegetation that may explain the location of species in the stations. The strong spatio-temporal fluctuations of the Shannon and Weaver index and the Piélou equitability in localities 1 and 3 show a great instability in the structure of the community of these localities. This shows the variability of environmental conditions. Moreover, the low fairness indices recorded in the other localities 1 and 2 are due to the high relative abundances of the *Sepedon (P) ruficeps* and *Sepedon* (*P*) *trichrooscelis* species, which account for almost 50% of the individuals in these localities. Indeed, according to Thienneman[18], "when the conditions of life in a given environment are favorable, many species are observed and each one is represented by a small number of individuals and the index of diversity is then high. When conditions are unfavorable, a small number of species are found, but each species is represented by a large number of individuals and the value of diversity is thus low ".The study of the dynamics of the Diptera Sciomyzidae is very important for the implementation of interventions to control the mollusc's intermediate hosts of schistosomiasis in Benin. Analysis of the seasonal variation shows that the low catch rate observed from January to June corresponds to the dry season and is due to the fact that in the dry season the water level becomes low and induces the low availability of the food resources in the environment. The increase in the July catch in December was due to a decline in the level of rainfall from the heavy rains of May and June, the concentration of mollusc-prey and the environment that is becoming increasingly accessible. The significant seasonal variations observed in all localities appear to be directly related to the prevailing media and rainfall conditions. Our results are generally consistent with those obtained by Verbeke[23] in the Democratic Republic of Congo in the Garamba National Park, where local weather conditions, particularly rainfall and those of southern Benin, are very similar[24]. Verbeke[22], established that the voltinism curves of sciomyzids harvested (787 specimens belonging to 11 species of Sepedon) are inverse to rainfall curves. In Brazil, authors Mello & Bredt[13], Knutson & Carvalho[8], obtained similar results. The increase in the number of catches, up to a maximum, is thus partly due to the gradual growth of the natural success rate of the development cycles. In the prospected stations, the specific richness and the fluctuations of observed populations vary slightly or very remarkably. They depend on environmental and biotic factors such as rainfall and temperature, prey available in quality and quantity, their accessibility, the impact of human and animal presence in the sites.

Principal Component Analysis (PCA) and Correspondence Factor Analysis (CFA) applied to the set of data on environmental variables and abundance of Sciomyzidae species showed that the distribution of species is under- Influence of temperature and rainfall. This result agrees with those of Gbedjissi et al[5]. The ecological characteristics of each site define two large areas formed by groups I and II. Sciomyzidae diptera dynamics are very important, as is the knowledge of the seasons in each region for the control of phenology, flight periods and mass farming of this Diptera in the implementation of Effective and cost-effective. The study could also be improved by increasing the frequency of collections and including other regions.

CONCLUSION

Throughout a year, it is always possible to capture Sciomyzidae in the wild. Harvest periods are very good for 5 months, from July to November. The maximum number of species can be caught in July-August and September. The specific wealth of each locality, established in this work, is probably provisional. The factors of the environment cause daily movements of individuals to shelters. It appears that the different localities are sensitive to seasonal variations. Maximum efficiency is at the beginning and end of the day. By increasing catch duration, number of outings, sampling areas and other landscape types, other species may be found in Benin. This data represents a source of information that could guide the implementation of any strategy for the control of intermediate host molluscs of schistosomiasis in Benin by targeting the best ecological conditions and containing a high number of Sciomyzidae.

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