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Study on population dynamics of black flies imagos

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Abstract
A study was conducted on three dates in three different months and four micro-niches at Assop falls to identify the species of Black flies, ascertain the relative abundance/distribution of black flies in various micro niches based on reproductive pattern, to ascertain if environmental and anthropological factors associated with ponds/rivers is important for accurate predictions at the generic levels. There was a $P<0.05$ level of significance based on variations on dates of collections, between species identified, relative site variation and numerical strength of the collected species and abundance of *Simulium* on various microniches/microhabitats (tree trunks, rocks and water surfaces). Although no significant difference ($P>0.05$) based on sexual dimorphism at various points was established. The results when compared to previous studies carried out in same vicinity about three decades ago indicated that the distribution and abundance of black flies in Assop falls were influenced by environmental changes and by human activities.

Keywords: Black flies, population, dynamics, environmental and anthropological-effects

1. Introduction

Black flies are not easily identified because they are species complexes composed of two or more morphologically similar species with the species complexes posing challenges for taxonomic and parasitological studies as well as control efforts [1]. Cytotaxonomic study which involves identification using the natural banding pattern of the polytene chromosomes of the salivary gland of the larvae of Simuliids, observed under the microscope to reveal the existence of structural rearrangements otherwise known as inversions has long been used in the taxonomy of black flies [2-3]. Early studies in West Africa revealed nine cytoforms [4-7], with the various sibling species showing differences in their geographical distribution and in their roles as vectors of onchocerciasis [8]. Subsequent studies have broadened the range of known differences between the sibling species, which affect their importance in the transmission of onchocerciasis [6, 8]. Early findings have shown that there were geographical variations among West African populations of *S. damnosum* s.l. and that these were related to savannah and forest environment [9]. The savannah-dwelling vectors of onchocerciasis are reported to transmit the blinding form of onchocerciasis, while the forest-dwelling vectors transmit the non-blinding form of the disease known as onchodermatitis [10-12].

Relatively little is known about black fly longevity, but it seems that adults of most species live for 3 – 4 weeks [13]. They undergo complete metamorphosis with both adults' males and females feeding on plant juices and naturally occurring sugary substances, but importantly, only females take blood meals of mammals and birds for the maturation of eggs although few are autogenous [14-18]. Thereafter, they breed in shallow, fast flowing waters of streams and rivers with high oxygen content and depositing their eggs in sticky masses or strings, often on submerged objects, such as rocks, leaves, and aquatic vegetation. The potential of black fly is influenced by many factors such as: breeding site characteristic, seasonal abundance, flight range, mating and oviposition behaviors [13-19] and the major breeding site characteristic associated with the distribution and population dynamic in lake or reservoir outlets are stream/rivers size, food supply, substratum, current velocity, depth, light and physicochemical conditions [20-23]. They have been reported to produce irritations and itches, toxic saliva and their bites lead to formation of vesicles, the resulting ulcers often prone to secondary infections and are important in the transmission of onchocerciasis – a form of filarial infection due to *Onchocerca volvulus* and in sensitive individual's, restlessness and allergic reactions may prevail [24-25].

Crosskey [26-30] recognized five Onchocerciasis zones in Nigeria which includes: Borgu-Sokoto zone, the Mid-Northern zone, the North Eastern zone, the Southern Adamawa zone and the South-Western zone, and that these zones based on other reports such as those of Wyatt [31] and Onuigbo [32] could be about 390,000km^2.

Assop Falls is located in the Mid-Northern zone and is popular because of agricultural activities, source of water for household use, fishing and irrigation purposes and for tourism. Unfortunately, the river system that forms the basis of agriculture in the area favours the breeding of black flies in large numbers and is a serious constraint to further agricultural development in the area. Despite the contributions of Assop Falls in ensuring food security and other economic activities, the menace of black flies in the area has not been given serious attention. Although, research in the past has been carried out on the relative abundance and the species complexes of *Simulium* in the area, no research has been carried out on the dynamics of *Simulium* abundance and distribution. It is envisaged that only through this sort of research that the attention of the Onchocerciasis Control Programme (OCP), the African Programme for Onchocerciasis Control (APOC), World Health Organization (WHO) and other Governmental and Non-Governmental and Development Organizations (NGDOs) can be attracted to come to the aid of Assop people. Opara *et. al.,* [33] has argued that the capture of adult flies can be used as a means of following the dynamics of *Simulium* abundance and distribution and thus the level and magnitude of parasite transmission.

The aim of this research work is to evaluate the species abundance/diversity of black flies in various micro-niches of Assop falls in Riyom L.G.A. of Plateau State, Nigeria, with the specific objectives of identifying the collected Black flies species within the various micro-niches, ascertain the abundance/distribution of black flies in various microhabitats based on reproductive pattern, ascertain if environmental factor associated with ponds/rivers is important for accurate predictions of Black flies at the generic levels, ascertain if past efforts at curtailing the menace has been successful, ascertain if after three decades of previous reports with recorded intermittent decrease in numbers that some species have become resistant to anthropological and environmental factors or that outright competition would have enabled few of the species to survive in a competitive environment.

2. Materials and methods

2.1 The Study Area

The study site was Assop falls in Hawan Kibo Village located in Riyom Local Government Area of Jos Plateau State (Figure 1), North Central Nigeria where previous studies by Roberts and Irving-Bell [34] had reported thirteen species of adult black flies (Figure 2 and 3). It is located 57 km South-West of Jos, naturally endowed with a rocky bed and is a fast flowing perennial River (10 m wide), descends the western edge of Jos Plateau in Central Nigeria from a height of 1000 m to 7000 m over a distance of 4 km and projects a cool serene atmosphere. The site is a Guinea- Savannah on the slope and top of a mid-altitude of ridge of Jos Plateau beside the Jos-Kagoro road about 70 km from Jos City. The area has vegetation comprising of gallery forests surrounded by grasslands and the river feeds the picturesque rapids and falls drains point of the Jos Plateaus Nigeria. Its headquarter is in the town of Riyom to the north of the Area at 9°38′00″N 8°46′00″E / 9.63333°N 8.76667°E / 9.63333; 8.76667, having a land mass area of 807 km² and a population of 131,557 as at the 2006 census, and is predominantly dominated by the Beroms. The LGA has boundaries with Kaduna and Nasarawa State and is the gateway to the State when coming from the East and from Abuja (Figure 1). Usually, two dry seasons are recorded in the area i.e. the raining season from May to October while the dry season from October to April.

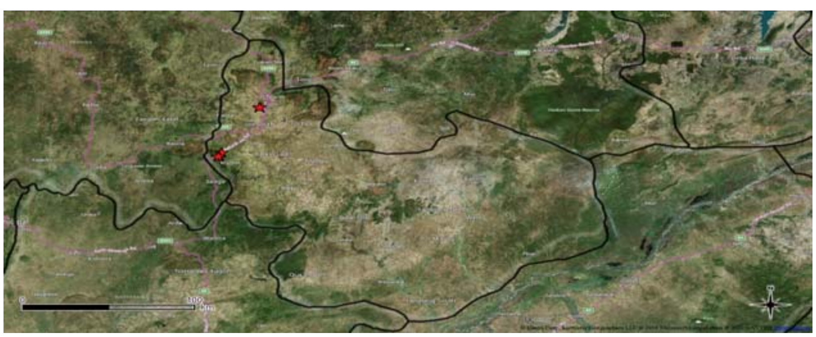

Fig 1: Map of Plateau State with Jos as headquarters with a star while the study site Assop Falls has double stars

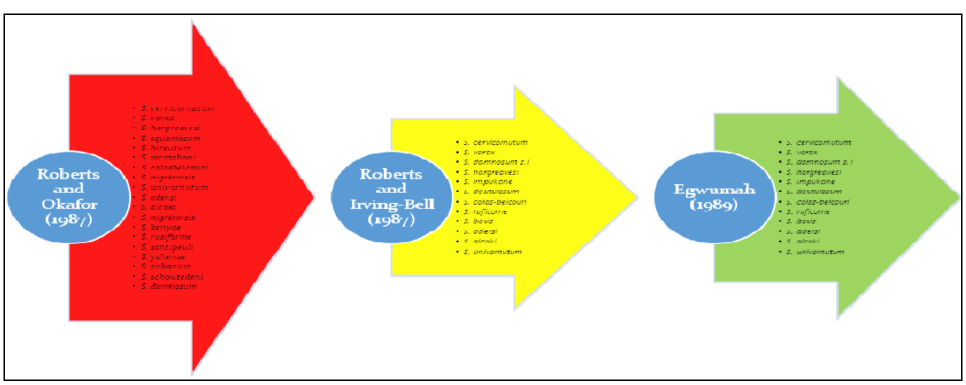

Fig 2: A schematic representation of the decline in number of the larvae species of black flies at Assop Falls, Nigeria

S. cerviconutum; S. vorax; S. damnosum SL; *S. hargreavesi; S. colasbelcouni;*

S. impukane; S. detulosum; S. bovis; S. adersi; S. alcoki; S. odersi; S. rusififorme;

S. univornutum- ***By* Roberts and Irving-Bell (1985)**

Fig 3: Schematic representation of adult black flies synchronizing with the larvae collected by Roberts and Irving-Bell (1985)

2.2 Collection of Samples

Samples of black flies were collected once in every month with the aid of a hand net between the months of November, 2015 and January, 2016 at four different sites tagged micro-habitats/ microniches (tagged A, B, C, D) (Figure 4). Human activities such as swimming, washing of clothes and tourism takes place at site A, and B. Site C is an area of cattle grazing with abundant grasses along the river bank. Mostly, cattle rest and drink water at site D. During the collection of samples, the surface water temperature was measured and found to range between 16-24 ºC. The collected flies were placed in specimen bottles and the bottles placed in ice block. Each of the specimen bottles was labelled with the samples from each micro-niches, the month, and day of collection, date and time of collection, then conveyed to the laboratory where they were analysed and then maintained in a refrigerator at 4^0C as described by Eberhard [35].

Fig 4: Pictures of various microniches/microhabitats where adult black flies were caught

2.3 Identification of Species and Laboratory Processing

The black fly *Simulium* (Diptera*:* Simuliidae) is a small, sturdy, hump-backed dark flies (3-6 mm long) Nematocera however, with the head attached on a typically humped shiny thorax [36-39]. Adult black flies were identified through their physical features such as body size (5mm), shape (relatively robust with arched thoracic region) and other features as described by [16, 36, 40]. *Simulium* species were separated from each other using physical separation and stored in specimen bottles with 80% ethanol and labelled according to collection sites and dates.

2.4. Statistical Analysis

Data collected was analyzed using the Univariate analysis for differences between subject factors i.e. species and areas, Post hoc test for least significant difference of areas and the Multivariate analysis of variance [41] was used to compare the abundance and distribution of black flies for the different months and also to establish if there was significant difference across all sampling dates for all sites.

3. Results

3.1 Relative Abundance of Black Flies

A total of four (4) species of *Simulium* were caught and identified. Of this number, 300 were identified to be *S. damnosum* (28.2%), 225 to be *S. yahense* (17.4%), 185 to be *S. vorax* (21.1%), 290 to be *S hargreavesi* (27.3%), and others to be 65 (6.1%) making a total number of flies caught to be 1062 (Table 1). The result shows that *S. damnosum* was the highest abundant species in point A and the lowest in point C which may be due to the rate of human activities which is high at point C and D while *S. vorax* recorded the highest species abundance at point C and the lowest at point B. *S. yahense* recorded its highest species abundance at point B and the lowest at point D. *S hargreavesi* recorded its highest species abundance at point B with its lowest at point A. Relative point variation is as shown in Figure 5, while multiple comparisons between points shows no significant difference at 95% confidence of interval (Table 2). Based on multiple comparisons between species (Table 3), a significant difference was observed between *S. damnosum* and *S. vorax* and also between *S. damnosum* and *S. yahense* at 95% confidence of interval.

Table 1: Relative Abundance of Black flies Identified

Site/month	*S. damnosum*	*S. vorax*	*S. yahense,*	*S hargreavesi*	Others	Total
Point. A Nov	22	13	20	20	15	90
Dec	16	20	15	18	0	69
Jan	43	15	37	30	1	126
Total	81	48	72	68	16	285
Point B Nov	18	6	18	21	0	63
Dec	20	13	20	25	0	78
Jan	40	12	35	32	1	120
Total	78	31	73	78	1	261
Point C Nov	18	18	15	28	23	102
Dec	15	15	18	10	2	60
Jan	35	21	18	31	5	110
Total	68	54	51	69	30	272
Point D Nov	24	25	12	20	18	99
Dec	18	13	10	28	0	69
Jan	28	14	7	27	0	76
Total	70	52	29	75	18	244
Grand	297	185	225	290	65	1062

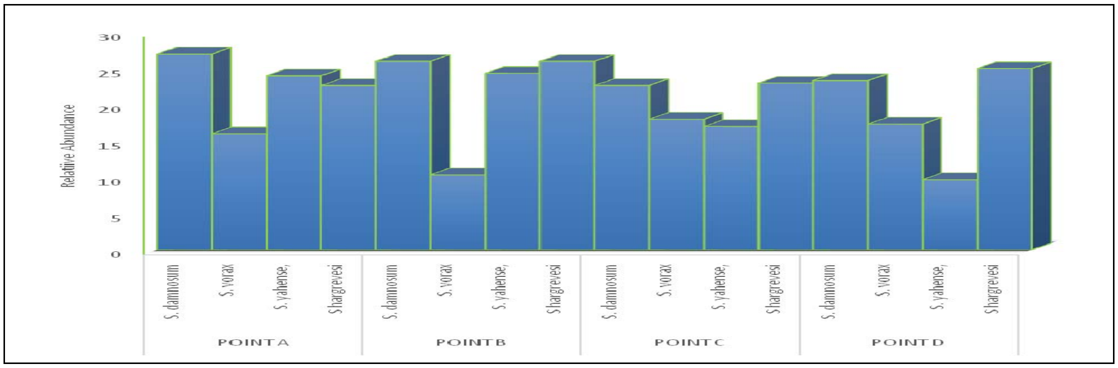

Fig 5: Relative point variation in the abundance of *Simulium* species

Table 2: Multiple Comparisons between Points

(I) point	(J) point	Mean diff (I-J)	Std Error	Sign	95% confidence interval	
					Lower bound	Upper bound
Point A	Point B	0.750	3.260	0.820	-5.890	7.390
	Point C	2.250	3.260	0.495	-4.390	8.890
	Point D	3.583	3.260	0.280	-3.057	10.224
Point B	Point A	-0.750	3.260	0.820	-7.390	5.890
	Point C	1.500	3.260	0.649	-5.140	8.140
	Point D	2.83	3.260	0.391	-3807	9.474
Point C	Point A	-2.250	3.260	0495	-8.890	4.390
	Point B	-1.500	3.260	0.649	-8.140	5.140
	Point D	1.333	3.260	0.685	-5.307	7.940
Point D	Point A	-3.583	3.260	0.280	-10.224	3.057
	Point B	-2.83	3.260	0.391	-9.474	3807
	Point C	-1.333	3.260	0.685	-7.974	5.307

Based on observed means, The error term is mean square (Error) = 63.771

Table 3: Multiple Comparisons between Species

(I)species	(J) species	Mean diff (I-J)	Std Error	Sig	95% confidence interval	
					Lower bound	Upper bound
S. damnosum	*S. vorax*	9.333*	3.260	0.007	2.692	15.974
	S. yahense	6.000	3.260	0.075	-0.640	12.640
	S. hargreavesi	0.583	3.260	0.859	-6.057	7.224
S. vorox	*S. damnosum*	-9.333*	3.260	0.007	15.974	-2.692
	S. yahense	-3.333	3.260	0.314	-9.974	3.307
	S. vorax	-8.750*	3.260	0.011	15.390	-2.109
S. yahense	*S. domnosum*	-6.000	3.260	0.075	-12.640	0.640
	S. vorax	3.333	3.260	0.314	-3.307	9.974
	S. hargreavesi	-5.416	3.260	0.106	-12/057	1.224
S. hargreavesi	*S. damnosum*	-0.583	3.260	0.859	-7.224	6.057
	S. vorax	8.750	3.260	0.11	2.109	15.390
	S. yahense	5.416	3.260	0.106	-1.224	12.057

Based on observed means, The error term is mean square (Error) = 63.771. * The mean difference is significant at $P<0.05$ level of significance

3.2 Monthly Variation of Species

Monthly variation in relative abundance of *Simulium* species encountered at various points is as shown in figure 6 below. The highest number of flies was caught in the month of January (425), while the least number was caught in December (274). There was decrease in population of flies in November but a progressive increase in the number of flies from December to January was recorded (Table 4). Based on reproductive pattern, more number of females was caught than their males' counterpart (Table 4). Multiple comparisons of species based on gender (reproductive) pattern indicate that a significant difference was observed between *S. damnosum* and *S. vorax* and also between *S. damnosum* and *S. yahense* at 95% confidence interval (Table 5). A figurative representation of reproductive pattern is as shown in Figure 7.

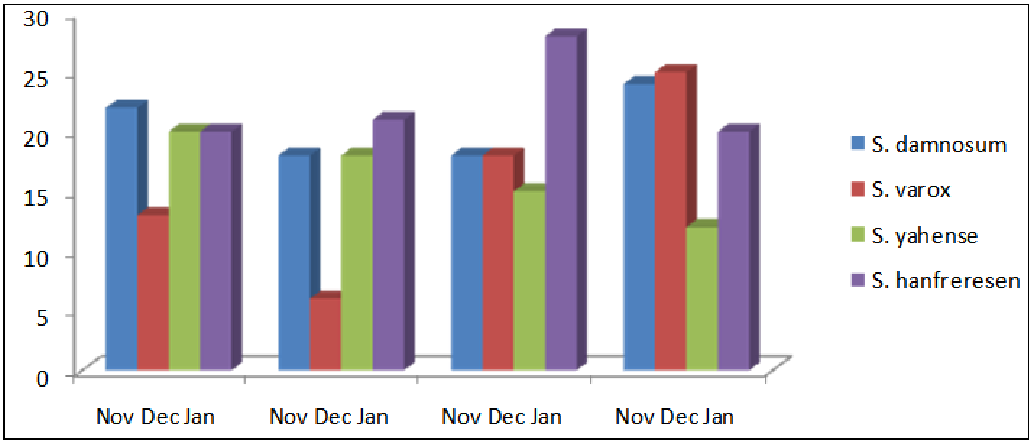

Fig 6: Relative monthly variation in the abundance of *Simulium* species

Table 4: Abundance/diversity based on gender (the assume reproductive pattern) of black flies

Months	Species								
	S. damnosum		***S. vorax***		***S. yahense,***		***S hargreavesi***		**Total**
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	
November	32	50	24	38	11	54	30	59	298
December	36	33	35	26	35	28	45	36	274
January	58	88	34	28	54	43	60	60	425
Total	126	171	93	92	100	125	135	155	997
Total number of Males to Females 454 (45.54%): 543 (54.46%)									

Table 5: Multiple Comparisons based on species and gender (reproductive pattern)

(I)species	(J) species	Mean diff (I-J)	Std Error	Sig	95% confidence interval	
					Lower bound	**Upper bound**
S. damnosum	*S. vorax*	18.666	9.389	0.064	-1.238	38.572
	S. yahense	11.666	9.389	0.232	-8.238	31.572
	S. hargreavesi	1.166	9.389	0.903	-18.738	21.072
S. vorax	*S. damnosum*	-18.666	9.389	0.064	38.572	1.238
	S. yahense	-7.000	9.389	0.467	-26.905	12.905
	S. vorax	-17.500	9.389	0.081	-37.405	2.405
S. yahense	*S. domnosum*	-11.666	9.389	0.232	-31.572	8.238
	S. vorax	7.000	9.389	0.467	-12.905	26.905
	S. hargreavesi	-10.500	9.389	6.280	-30.4045	9.405
S. hargreavesi	*S. damnosum*	-1.166	9.389	0.903	-21.072	18.738
	S. vorax	17.500	9.389	0.81	-2.405	37.405
	S. yahense	10.500	9.389	0.280	-9.405	30.405

Based on observed means, The error term is mean square (Error) = 264.500

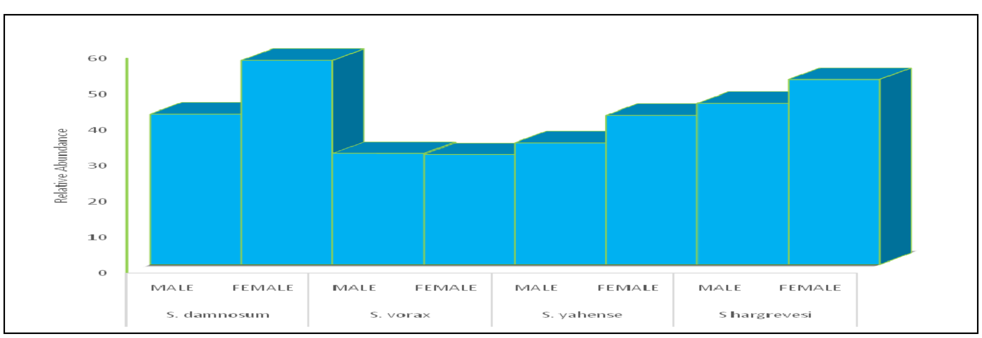

Fig 7: Relative Abundance based on Reproductive Pattern of Species

3.4 Abundance of Species Based on Microhabitat

Collected species based on microniches or microhabitat indicated that more species were collected on tree trunks than on rocks and water surfaces (Table 6). Multiple comparisons indicate that a significant difference was established between Tree trunks and water surfaces and also between Rocks and water surfaces at 95% confidence interval (Table 7). Multiple comparisons based on species abundance in microniches indicate that no significant difference was observed between species (Table 8). Figurative representation is as shown in Figure 8.

Table 6: Abundance/Diversity Based On Microhabitat of Black Flies

Habitat	Specie	Point A	Point B	Point C	Point D	Total
Tree truck	*S. damnosum*	22	18	18	24	82
	S. vorax	13	6	18	25	62
	S. yahense,	20	18	15	12	65
	S hargreavesi	20	21	28	20	71
Total		75	63	79	81	298
On rocks	*S. damnosum*	18	15	20	16	69
	S. vorax	13	15	13	20	61
	S. yahense,	10	18	20	15	63
	S hargreavesi	28	10	25	18	81
Total		69	58	78	69	274
Surface water	*S. damnosum*	43	40	35	28	146
	S. vorax	15	12	21	14	62
	S. yahense,	37	35	18	7	97
	S hargreavesi	30	32	31	27	120
Total		125	119	105	76	425

Table 7: Multiple Comparisons based on microhabitats

(I)Habitat	(J)Habitat	Mean diff (I-J)	Std Error	Sig	95% confidence interval	
					Lower bound	Upper bound
Tree trunk	On rock	1.500	2.691	0.591	-3.959	6.959
	Surface	-7.937*	2.691	0.006	-13.396	-2.478
On rocks	Tree trunk	-1.500	2.691	0.581	-6.957	3.959
	Surface	-9.437*	2.691	0.001	-14.896	-3.978
Surface water	Tree trunk	7.937*	2.691	0.006	2.478	13.396
	On rock	9.437*	2.691	0.001	3.978	14.896

Based on observed means, The error term is mean square (Error) = 57.965; *The mean difference is significant at $P<0.05$ level of significance.

Table 8: Multiple Comparisons based on Species Abundance in Microniches

(I)species	(J) species	Mean diff (I-J)	Std Error	Sig	95% confidence interval	
					Lower bound	Upper bound
S. damnosum	*S. vorax*	2.416	3.108	0.442	-3.887	8.720
	S. yahense	0.583	3.108	0.852	-5.720	6.887
	S. hargreavesi	3.583	3.108	0257	-2.720	9.887
S. varox	*S. damnosum*	-2.416	3.108	0.442	-8.720	3.887
	S. yahense	-1.833	3.108	0.559	-8.137	4.470
	S. vorax	1.166	3.108	0.710	-5.137	7.470
S. yahense	*S. domnosum*	-0.583	3.108	0.852	-6.887	5.720
	S. vorax	1.833	3.108	0.559	-4.470	8.137
	S. hargreavesi	3.000	3.108	0.341	-3.303	9.303
S. hargreavesi	*S. damnosum*	-3.583	3.108	0.257	-9.887	2.720
	S. vorax	-1.166	3.108	0.710	-7.470	5.137
	S. yahense	-3.000	3.108	0.341	-9.303	3.303

Based on observed means, The error term is mean square (error) = 57.965**.**

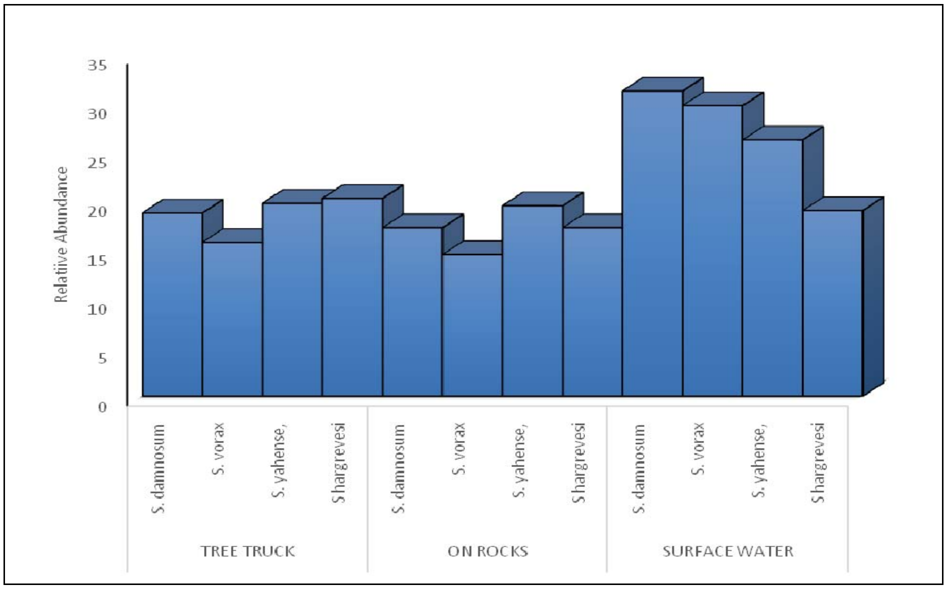

Fig 8: Relative Abundance of Species based on Microhabitats

4. Discussion

4.1.1 Relative Abundance of Black flies Identified in Assop Falls

In this study, a total of 1062 flies were caught comprising of four (4) species of *Simulium* and few unidentified flies species. The reduction in the species of black flies collected agrees with Mafuyai *et al.,* [12] who recorded some variation in the relative abundance of the species identified as earlier reported in previous publications by Roberts and Irving-Bell [34]. Whereas in the previous studies by Roberts and Irving-Bell [34] and Mafuyai *et al.,* [12], *S. sanctipauli, S. Soubrense* and *S. squamosum* which are forest species were collected in the same vicinity, our inability to collect them in this present study could be attributed to probably climate change, deforestation or increase in human population around the vicinity. The variation in the relative abundance of the species identified could also be attributed to seasonal changes and probably changes in water parameters as evidenced from the fluctuations of temperatures of between 16-24 ^{0}C recorded within the study period. A study in Brazil found that environmental changes related to urbanization led to decreased abundance and loss in the number of species of the black fly fauna. It observed that Simuliidae species were present in streams with intermediate urban pollution impacts, but absent in heavily impacted sites. This is because changes in physico– chemical properties of water affect the oxygen flow and equally affect the distribution of flies [42] and as pointed by Ciadamidaro *et al.,* [43], since black flies can be considered good environmental indicators to assess ecological health of both water courses and surrounding landscapes, this invariably implies that blackly larvae abundance is an indication of quality water.

The result further indicated that *S. damnosum* was the most abundant species caught in all the microniches with the highest caught in human activity areas which could mean a potential health hazard. Surprisingly, *S. hargreavesi* and *S. yahense* were also are present in human activity areas but tend to show large presence in cattle grazing areas. Of the American *Simulium* species, Dalmat [44-46]; Wilton and Collins ([47]) have both reported that *S. ochraceum* is markedly anthropophilic, while, *S. metallicum* and *S. callidum* are markedly zoophilic in their blood feeding behaviour. Additionally, Millest *et. al.,* [48], observed that in the forest areas, members of the *S. sanctipauli* are more zoophilic than *S. yahense*, which would make them less efficient vectors and that the breeding of *Simulium sanctipauli* in large rivers is responsible for the high density yield for biting flies unlike *Simulium yahense* which breeds in smaller streams and rivers as such usually found at lower biting densities.

4.1.2 Relative Monthly Variation in the Abundance of *Simulium* Species and reproductive pattern

Monthly variation in relative abundance of *Simulium* species encountered at various points shows that there was a steady increase in the number of collected black flies from November to January. This agrees with the findings of Ubachukwu and Anya [49] that observed similar increase in fly population in Nkpologu, Uzo-Uwani Local Government Area of Enugu State during the dry season with harmmattan but contradicts the findings of Opara *et. al*., [33] who observed the highest number of flies in September in Cross River State, Nigeria. Several fluctuations have been observed with the population of *S. damnosum* sl and this is largely dependent on the number of suitable sites. Breeding are known to be all year round in the rain forest zone of West Africa, while some rivers in the Savannah region may lose their breeding sites both at the peak of the wet season when rocky surfaces are completely flooded [50], and at the heart of the dry season, typical of Northern Nigeria, when the water courses dry up [51]. More females 543 (54.46%) of identified species of black flies than males 454 (45.54%) were caught in this study. According to Crosskey [51], he noted that occasionally, Simuliids fly in huge swarms so thick that they appear as great clouds, but in their search for food, both males and females seek out plant juices and other sources of natural sugars and in addition, the females of most species of black flies bite mammals or birds in order to obtain blood which is essential for the maturation of the eggs in their ovaries. The high number of females could portend their potential capabilities.

4.1.3 Abundance/Diversity Based on Micro niches of Black flies

The result shows that more black flies were collected on tree trunks and on rock surfaces than on water surfaces with a significant difference established at $P<0.05$ level of significance. *S. damnosum* despite being large in numbers collected on tree trunks and rocks were also the highest in number collected on water surfaces. Their abundance on tree trunks could be attributed to sourcing for shelter or alternative food source. As noted by Davies *et. al.,* [20]; Burgin & Hunter [52]; Myburgh *et. al.,* [53], adult black flies, both male and female, feed on sugars that provide them with carbohydrates for longetivity and energy to fly, but importantly as reported by Braveman [54]; Howell and Holmes [55]; Palmer [56], female black flies of some species are also blood feeders and that these blood meals provide the female with proteins that certain species of black fly require in the development of eggs. In addition, Crosskey [51] noted that although most species of buffalo flies alight partially immersed objects such as rocks, vegetation or debris (such as logs and sticks) in order to oviposit, several species such *S. metallicum* are exceptional in that they drop their eggs on the surface of water or on floating leaves, whilst they are on the wing during an oviposition flight.

5. Conclusion

The reduction in the number of species caught at Assop could be as a result of changes or increase in either abiotic or biotic factor which would have been non-conducive for others species or probably just an act of the survival of the fittest that would have caused migration. Although it has been noted that *S. damnosum* and *S. sirbanum* are savannah species while others like *S. yahense, S. santipauli, S. soubrense, S. sqaumosum* are forest dwelling, and since Assop fall is in the savannah region and gradually adapting to climate change, the possibility could be for the migration of other species to suitable sites that could best support their rate of water evaporation.

6. Recommendation

It is recommended that further research work could be carried out in the same vicinity after some months or years to ascertain if the same species are still available, gone on migration to other areas and/or reinvasion of the area by species formally reported by Roberts and Irving-Bell ([34]).

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