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***Research Article***

# Seasonal Abundance and Diurnal Activities of *Simulium damnosum* Theobald (Diptera Simuliidae) Complex in Gurara River of Kagarko Local Government Area of Kaduna State

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**ABSTRACT**

Black flies (Diptera: Simuliidae) are medically and ecologically significant insects of importance and are the sole vectors of onchocerciasis. This study aimed to assess the abundance and diurnal activities of blackflies at the Gurara River in the Kagarko Local Government Area of Kaduna State. Blackflies were collected through the Human Landing Catch (HLC) method following WHO protocols between 7:00 am and 6:50 pm over twelve months (July 2019 – June 2020). Three human collectors sat at the banks of breeding sites, wore shirts and trousers rolled up to the knees, and constantly watched their lower legs for landing blackflies, which were caught individually before procuring a blood meal. Blackflies were caught by being trapped in a polypropylene tube inverted over them. Temperature and relative humidity were recorded using the whirling hygrometer. Data was analyzed using SPSS software statistical package version 25.0. A total of 3512 adult *Simulium damnosum* were caught. The highest number of blackflies caught was in August 2019 (28.5%). Relative humidity and temperatures were 89% and 260 °C, respectively. The abundance of blackflies and weather showed a significant correlation ($p < 0.05$). Seasonal blackfly abundance was higher in the rainy season (93.4%) than in the dry season (6.6%). The diurnal biting activity of the blackflies showed a bimodal biting pattern. The study showed a profusion of black flies in the study area, with black fly activities showing morning and afternoon peaks.

**Keywords:** Abundance; Blackflies; Diurnal; Season; Weather

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## INTRODUCTION

Black flies (Diptera: Simuliidae) are medically and ecologically significant insects and are the sole vectors of onchocerciasis. These flies are found around fast-flowing well aerated water bodies, hence increasing the risk of onchocercal blindness affecting up to 50% of adults in endemic communities (Abdullahi and Oyeyi, 2003). Transmission of disease relies on vectorial competence or capacity. In Nigeria, the incidence of *Simulium* constitutes a threat to the affected areas as the fear of blindness and the biting menace of the flies, results in the depopulation of fertile river valleys as well as farmlands ergo, making the vector a major threat to food security and an obstacle to socio-economic growth (Adler and McCredie). Furthermore, the morbidity from this disease results in decreased worker productivity. Skin disfiguration from disease can disrupt social relationships. In addition, the debilitating effects of

the disease result in loss of manpower hours; as affected individuals are usually unable to work; likewise, productive hours are lost by the individuals taking care of the sick. Blackflies are daytime biters (Diurnal) with host-seeking activity peaking around particular times of the day, depending on the duration of the blood feeding and oviposition cycles, depending on intrinsic preferences and host availability, blackflies obtain their blood meals in flexible proportions on humans (Anthropophagy) and non-human (Zoophagy) hosts (Hendy *et al*., 2018). Blackflies possess specialized mouthparts used to pierce the skin and ingest the blood meal containing microfilariae (mf). The relative abundance and biting density of different *Simulium* species may vary spatially, seasonally, daily, and hourly (Adeleke *et al*., 2010). Transmission intensity and onchocerciasis severity are a result of continuous exposure of individuals to *Simulium* bites. Consequently, quantification of host exposure (Daily, Monthly, and Annually) is important in understanding the scale of transmission and the impact that control measures may result on such transmission (Figueiro *et al*., 2014; Lamberton *et al*., 2014). Not all simuliidae behave the same at bait. Some species for example, *S. callidum* and *S. metallicum* are easily disturbed when either exploring the skin or sucking up blood. Such species which are 'nervous feeders' are more difficult to catch and in consequence, their reluctance to bite may be of limited importance in disease transmission (Service, 1977). A high degree of anthropophagy and biting density may suggest certain *Simulium* species as vectors of onchocerciasis but additionally, the efficiency (known as vector competence) of such species in acquiring microfilariae, allowing their development to the infective stage and surviving beyond this period is important.

## MATERIALS AND METHODS

### Study Area

The study was carried out along the Gurara river system between latitude $9^0$ 39" 58.3'N and longitude $7^0$ 52" 59.5"E in Kagarko Local Government Area in the Southern axis of Kaduna state. It is located some 45 minutes (about 31 km) from Kachia Local Government Area of Kaduna State in the Northern Guinea Savannah. It has a relative humidity of 79% with annual rainfall between 1200mm - 1300mm (Dalil *et al*., 2015). It has an elevation of 421 meters above sea level. Climate consists of two seasons; the wet season from May to October and the dry season from November to April. The Gurara River is located at a distance of about 1km from the Gurara village. The inhabitants mostly engage in agricultural activities such as farming and fishing and also some trading activities. They farm products such as ginger, maize, beans, yams and groundnuts. The people are mainly Koro, Jaba and some Fulani settlers. Kaduna state shares borders with Niger, Zamfara, Katsina, Kano, Plateau and Nassarawa States.

### Ethical Approval

Ethical approval with reference number MOH/ADM/744/VOL.1/933 was obtained from the Ministry of Health, Kaduna State. Signed informed consent was obtained from individual collectors after detailed explanations about the study. The collectors were treated with ivermectin (150 µg/Kg body weight given orally) prior to blackfly collections.

### Collection of Blackflies

The collection of blackflies was carried out over twelve months, from July 2019 to June 2020 covering both the wet and dry seasons (Iboh and Arong, 2015). Adult Blackflies were collected by three blackfly collectors from the Gurara River and its water courses for three consecutive days a week in every month during the period of collection (Lamberton *et al.,* 2014; Nascimento-Carvalho *et al.,* 2017). Collections were from three sampling sites marked as points A, B, C which were along the beginning and middle parts of the river banks. These sampling sites have the characteristics of being rocky, and hilly with considerable water bodies including rapids. Collections of blackflies were carried out by the Human Landing Catch (HLC) method (Nascimento-Carvalho *et al.,* 2017). Using standard Onchocerciasis Control Program (OCP) vector collector techniques, three human collectors sat at the banks of breeding sites and wore shirts and trousers rolled up to the knees and constantly watched their lower legs for landing blackflies which were caught individually before procuring blood meal. Blackflies were caught by being trapped in a polypropylene tube inverted over them. Captured flies were pooled according to hour of catch in each collection point and well labelled at hourly intervals and kept in a cold box for subsequent studies (Lamberton *et al.,* 2014, Iboh and Arong 2015, Hendy *et al*., 2018). Daily fly collections were taken between 7:00 a.m. – 11:50 a.m. and in the afternoon between 1:00 p.m. - 6:50 p.m. with 50 minutes of catch intervals and 10 - minute pauses (Nascimento-Carvalho *et al.,* 2017). Flies collected were recorded in data recording sheets. Weather conditions such as ambient temperature and relative humidity were recorded using the whirling hygrometer.

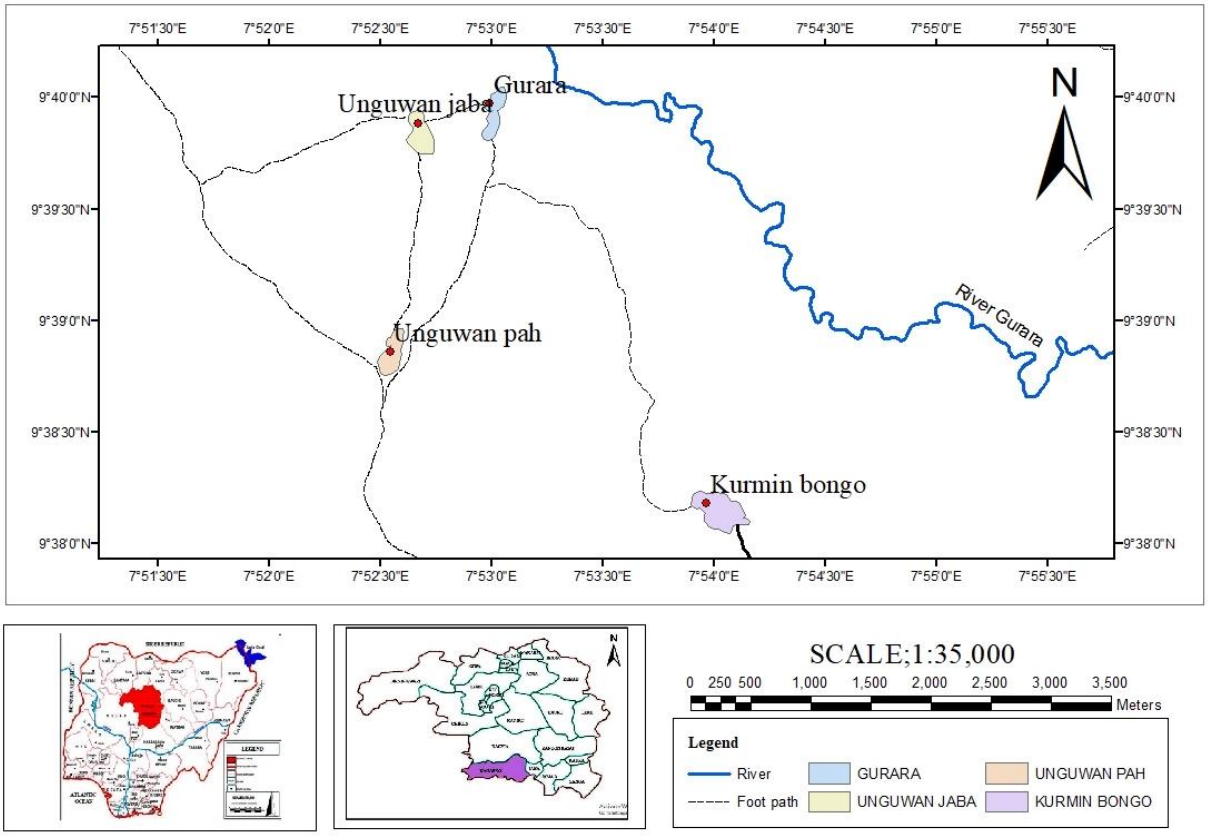


**Figure 1. Map of the Study Area**

**Data Analysis**

Descriptive statistics was employed to present simple frequencies. The Pearson correlation analysis was applied to compare the degree of relationship between fly abundance and weather data. The One Way Analysis of Variance (ANOVA) was applied to compare between groups (Mukhtar, 2003; Domino, 2015). Data was analyzed using SPSS software statistical package version 25.0.

## RESULTS

A total of 3,512 *Simulium* were collected along the Gurara river banks from July 2019 to June 2020. Figure 2. illustrates the variations in the abundance of blackflies as well as the relative humidity and temperatures recorded during the period of study. The mean temperature and relative humidity during the study period were 27.19$^0$c and 85.80% respectively. The highest number of blackflies caught was in August, 2019 with 1002 (28.5%) of the total flies caught. Relative humidity and temperatures were 89% and 26$^0$c respectively. This was followed by July with 887 (25.3%) of the total caught. Relative humidity and temperatures were 93% and 24$^0$c respectively. In September, 777 (22%) of the total flies were caught and recorded while the relative humidity and temperature were recorded as 73% and 27$^0$c. The least number of black flies were caught in January 2020 with only a single fly (0.03%) and December 2019 with 3 flies (0.09%). Relative humidity and temperatures in December 2019 and January 2020 were recorded as 5%, 13.3$^0$c and 4%, 13.6$^0$c in that order. In March, 120 flies were collected, while relative humidity and Temperature was 65% and 33$^0$c. Blackflies were more abundant in the rainy season (92.9%) than in the dry season (7.1%) (Figure 3).The Pearson correlation analysis ($r$) examined the relationship between the number of flies caught and weather data (Temperature and Relative Humidity) in both the dry and rainy seasons; and it revealed that the number of flies caught during the months of the dry season showed a significant and positive correlation to the temperature ($r$ = 0.347, $p$ = 0.000). On the contrary, no significant relationship was found between the number of flies caught and relative humidity ($r$ = 0.001, $p$ = 0.987). Conversely, during the rainy season, there was a significant but negative association between the number of flies caught and temperature ($r$ = -0.388, $p$ = 0.000). Likewise, the number of flies caught and relative humidity showed a significant but negative correlation ($r$ = -2.37, $p$ = 0.001). The Pearson correlation analysis equally examined the relationship between the abundance of flies and weather data (Temperature and Relative humidity)

during the study period and it revealed that there was a significant but negative relationship to the temperature ($r$ = -0.247, $p$ = 0.000) and relative humidity ($r$ = -0.156, $p$ = 0.003). Fig 3. shows the mean of blackfly abundance between the rainy season (93.4%) and the dry season (6.6%).

Figure 4. illustrates the diurnal activity of blackflies within the study period; which showed two biting peaks in the morning and afternoon. There were two morning peaks and one peak in the afternoon. The morning peaks were more distinct than the afternoon peak. The morning peak was between 8 - 10:50 am while the afternoon peak was between 2 - 2:50 pm. The peaks were separated by hours of low biting intensity between 9 - 9:50 and between 11 - 1:50 pm. The mean of temperature and relative humidity during the morning hours was 25.67$^0$c and 85.41% respectively while the mean of temperature and relative humidity during the afternoon phase was 29.01$^0$c and 85.36% respectively. The mean temperature and relative humidity during the evening hours was 28.45$^0$c and 87.76% respectively. The Pearson correlation ($r$), showed no significant correlation in the activities of the blackflies in the morning hours between temperatures ($r$ = 0.16, $p$ = 0.827) and relative humidity ($r$ = 0.063, $p$ = 0.405). There was however a significant but weak correlation in the activities of flies in the hours of the afternoon between temperatures ($r$ = -0.586, $p$ = 0.000) and relative humidity ($r$ = - 0.461, $p$ = 0.000). During the evening hours however, the correlation in the activities of the flies with temperature, showed a significant correlation ($r$ = -0.403, $p$ = 0.000) and in the same way with the relative humidity ($r$ = -0.598, $p$ = 0.000).

The one-way analysis of variance showed that the total number of flies caught during the three different periods of the day are not significantly different from each other $F$ (2, 361) = 1.107, $p$ = .332. Post hoc analyses using the Games-Howell post hoc criterion for significance indicated that the average number of black flies caught during the morning, afternoon and evening periods of the day were not significantly different from each other.

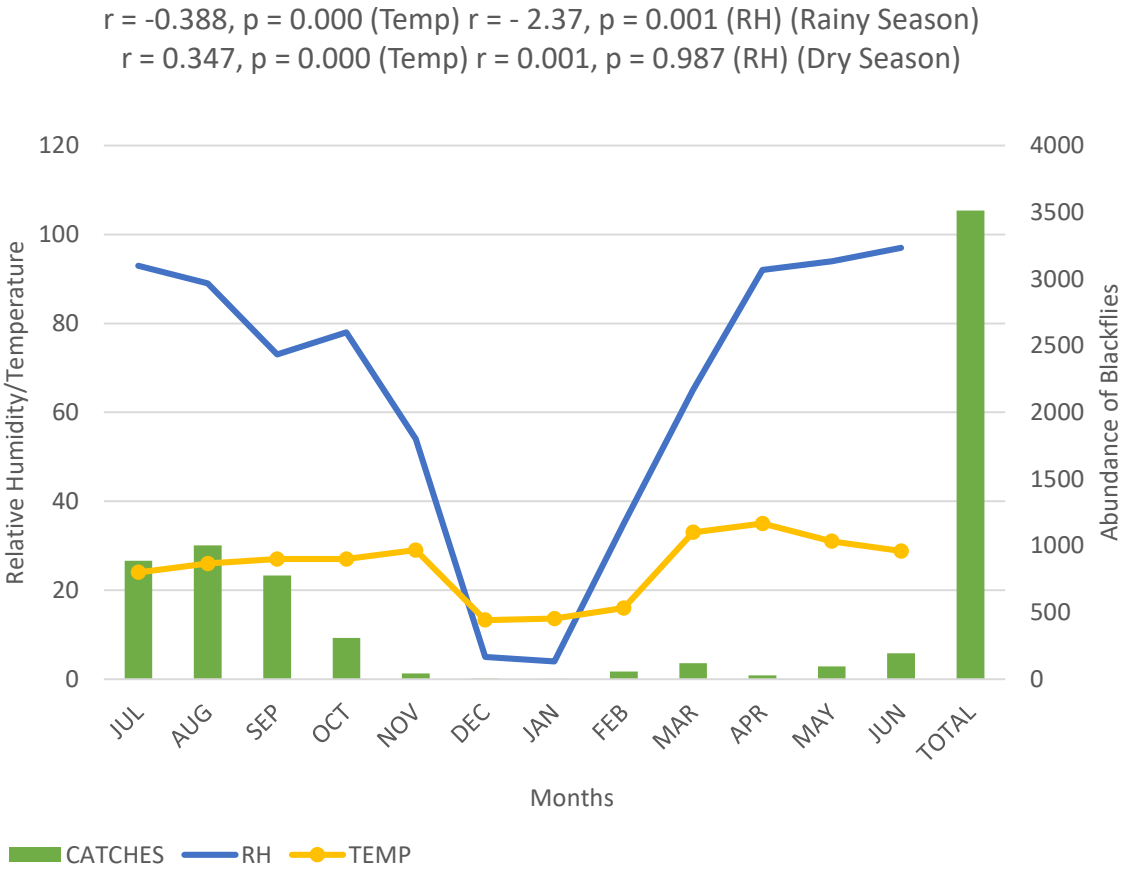


**Figure 2. Abundance of Caught Blackflies and Weather Data in Gurara River Recorded July 2019– June 2020**

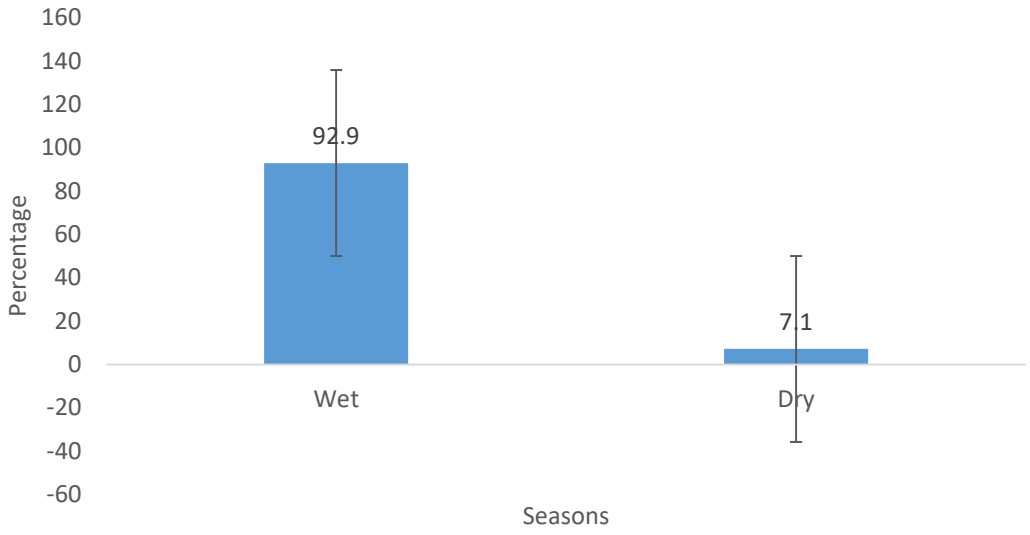


**Figure 3. Mean of Blackfly Abundance between the Rainy Season and Dry Season of the Period of Study**

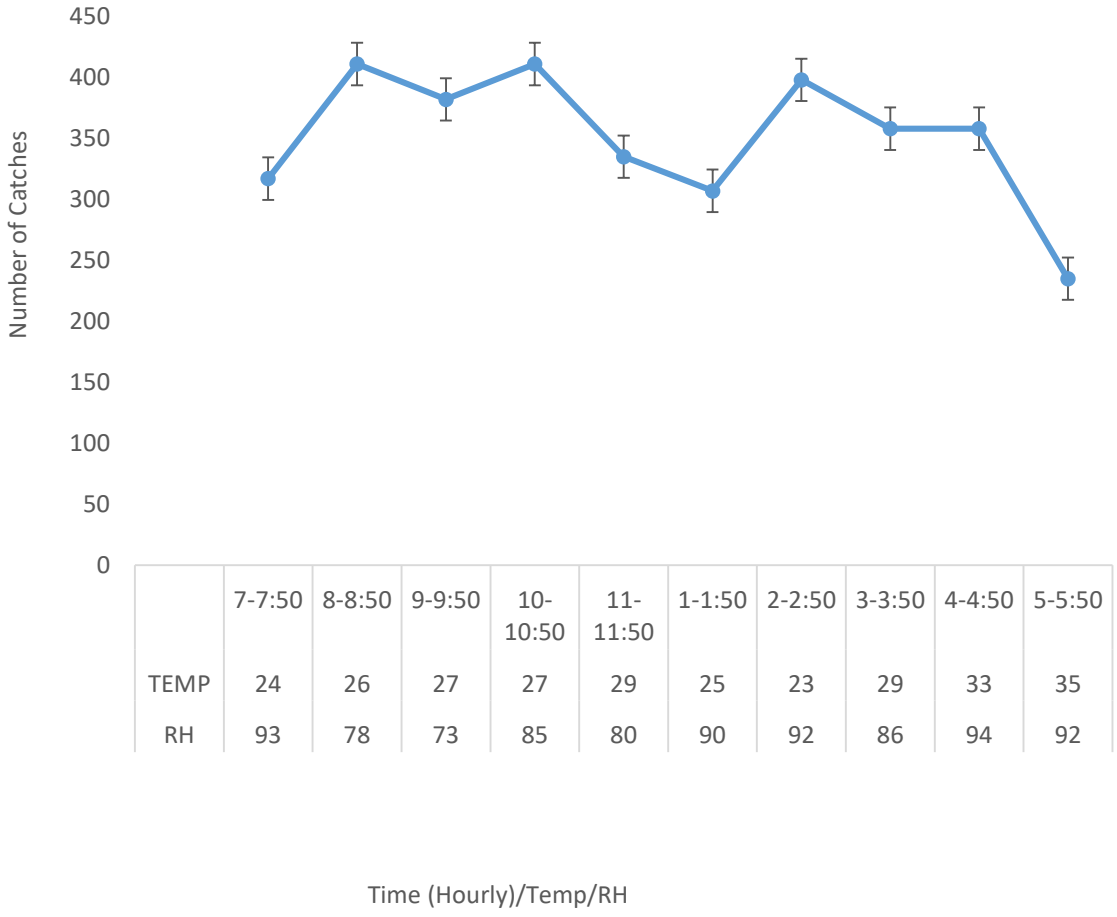


**Figure 4. Diurnal Activities of Caught Blackflies during the Study Period**

## DISCUSSION

This study revealed the presence of black flies in the catching points located along the Gurara River banks. Since blackfly abundance is dynamic, and can be linked to changes in flow and turbidity levels of water bodies, the hydro physical features of the Gurara River such as rocky and hilly terrain, fast-flowing/flooded waters etc., may perhaps be ascribed to the profusion of flies along the Gurara river banks (Nanjul *et al*., 2017). Rapids which form

favorable breeding sites for blackflies are formed from the African Precambrian basement rocks which usually break the flow of water (Mafuyai *et al*., 1996). These rocky basements and submerged substrata that provide support for aquatic stages of insects such as blackflies are found along the Gurara River.

Stationary human bait catches give useful measures of relative changes in fly densities. The difference in the monthly catches/densities of blackflies at the study site could be attributed to conditions such as temperature and moisture (relative humidity) which play an important role in the seasonal changes in blackfly densities (Zarrough *et al.,* 2016). This study recorded a marked increase in the abundance of flies from May to October after which a progressive decline was observed from November to April. The highest number of flies caught was recorded in August while the least was caught in January. The fly population in this study was distinctly higher during the rainy season than in the dry season. This agrees with Atting *et al.* (2005) where the highest density of flies was also recorded during the rainy season in a study conducted in Cross River state. Crosskey (1990) similarly reported that number of blackflies was typically higher during the rainy season than during the dry season in West Africa. This study showed a direct relationship between monthly relative humidity/temperatures and the relative abundance of the flies for the reason that most of the flies were caught at the peak of the rainy season (July-September) which also indicates *S. damnosum* to be a rainy season breeder along the Gurara river system. This assertion is consistent with Opara *et al.* (2005) who reported an abundance of *S. damnosum* during the period of heavy rainfall at the lower Cross River basin. The abundance of blackflies may be due to the spur of increased oxygen content of the water during the rainy season which causes the flies to emerge from pupae. Furthermore, increased oxygen content in the breeding sites may be accompanied by increased amounts of nutrients (detritus, bacteria, diatoms, and filamentous algae which constitute food required by *Simulium* larvae and the availability of preimaginal sites all of which enhance preimaginal development which results in an upsurge in the adult fly population during the rainy season (Opara *et al.,* 2005). Similar views were also posited by Zarrough *et al.* (2016) in a study conducted in two Sudanese foci of Abu Hameed and Galabat. Additionally, black fly activity which appeared from May to October could be attributed to the increase in the water levels of the river during the peak of the rainy season while an observed decrease in fly population and activity between November to April could be attributed to the low water and oxygen levels as earlier reported by Eyo *et al.* (2014). Having low fly densities during the dry season is not surprising as the dry season often stops rivers from flowing due to the low levels of the water bodies and as such, the rapids which epitomize the flies are reduced or absent and only resumes when the rainy season sets in (Ochu *et al.,* 2021; Oluwole *et al.*, 2009; Garms *et al.*, 2015). Crosskey (1990) argued that in West Africa, the biting activity of *Simulium damnosum* ceases completely or is reduced to trickles and resumes when rivers begin to flow during the rainy season. However, where the climate is practically uniform throughout the year, the rivers run continuously and as such, biting activity occurs all year round along the breeding sites (Crosskey, 1990). The possible migration of the adult flies to areas where there are favorable conditions for their survival could also be a plausible reason for low fly densities during the dry season as farming and other agricultural activities are almost completely absent thus they do not get their blood meals necessary for their survival. Taye *et al* (2000) affirmed that changes in the distribution pattern of blackflies occur annually in association with pronounced seasonal variations of the rainy and dry seasons in West Africa. These seasonal changes are accompanied by shifts in wind direction and also by the drying out of rivers which provides *S. damnosum* breeding sites (Cheke *et al*., 1992). However, the mechanism of dry season survival is still unproven; likewise, the length of larval life is not well known (Crosskey, 1959). Contrary outcomes to findings in this study have however been reported by Onah (2020) in a study conducted in Adani Enugu state Nigeria where a higher number of flies were recorded during the dry season. The biting activity of blackflies suggests that most anthropophilic blackflies are day biters, but different species may exhibit diurnal fluctuations in host-seeking activities. For instance, *S. naevi* in Kenya bite mainly from 0900 – 1130h and then again from 1400 - 1700h. In Guatemala, the three most important anthropophilic species have different biting profiles. *S. metallicum* bites from about 0700h more or less continuously until 17:30h but with a small peak of biting between 0800 - 1000h. Biting by *S.callidum* extends from about dawn to 0900h and again from 1500 or 1600h to twilight but with little activity at other times. Biting peaks of *S. damnosum* in West Africa are mainly in the mornings and afternoons as also shown from this study. In Nigeria, however, the biting cycle may vary seasonally and also from place to place (Crosskey, 1955). Blackflies often bite continuously from dawn to dusk but seldom at the same sustained level throughout the day. In this study,

there was a bimodal biting pattern with a morning peak around 8 - 11:50 am, an afternoon peak observed around 2 - 5:50 pm. The morning peak was higher than the afternoon peak though not statistically significant. This finding agrees with that of Busari *et al.* (2021). These biting peaks are consistent with reports in other endemic communities (Okolo *et al.,* 2004; Opara *et al*., 2005; Oluwole *et al.*, 2009; Lamberton *et al.*, 2014; Chikezie *et al.*, 2018; Onah *et al.*, 2020) but contradict Adeleke *et al* (2010) where three biting peaks were recorded in a study conducted in the Osun River South Western Nigeria and Barbiero and Trpis (1984) where a unimodal biting peak was observed in a study conducted in Liberia. Zarrrough *et al.* (2016) reported an unimodal and a bimodal peak of activities of blackflies in a study conducted in Abu Hameed and Galabat foci in Sudan respectively and attributed these to the variations in daily temperatures and illumination characterized by climatic conditions. The biting peaks could be a result of variations in weather conditions within the locality (Adeleke, 2010). There were occasions where rainfall disturbed catching activities as rainfall during catching days reduced the presence of flies to trickles. Temperature and relative humidity may have influenced biting activity as well. Likewise, weather conditions such as sunlight, and winds, may have also played a role in the biting activity of the flies since strong winds have been known to push the flies away. Blackflies like other hematophagous insects prefer higher temperatures which serve as a stimulus for probing and feeding (Zarrough *et al.*, 2016). The presence and biting activity of the flies has also been reported by Arrondo *et al.* (2017) to be affected by temperatures where it was stated that the optimal temperature for host-seeking activity of *S. erythrocephalum* was between $17.4^0$c and $22^0$c in the morning and between $22.17^0$c and $27.35^0$c in the evening. Temperature and relative humidity are sympatric (the higher the temperature the higher the relative humidity likewise, the lower the temperature the lower the relative humidity) (Adewale *et al.,* 1999, Petry *et al.,* 2006; Arrondo *et al.*, 2017). The reason for the biting peaks of blackflies is not so clearly understood. It is opined that an innate clock rhythm may be responsible. Since blackflies do not suck blood daily, the biting cycle may be loosely described as a circadian rhythm which by description requires a biological rhythm on a one - day periodicity (Crosskey, 1990; Opara *et al*., 2005; Akinsanya, 2019; Onah *et al.*, 2020). The biting pattern has some epidemiological implications especially as the biting peaks correspond to the outdoor activities of the people within the study area who engage mostly in farming, and some small-scale trading activities (the women engage in the frying and selling of cassava).These activities are usually done in the early morning toward afternoon which corresponds with the peak biting period of the vectors. This poses a connection in the man - fly contact and the risk of disease transmission by infective parous flies; as only aged flies can transmit the parasite. Conversely, disease intensity and transmission dynamics would be distinctly affected by changes in human practices (Opara *et al.,* 2005, Adeleke *et al.,* 2010).

## CONCLUSION

In conclusion, the study reported a seasonal variation of the blackfly population in the study area and a bimodal biting pattern of the blackflies was also established.

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**Authors Contributions:** Conceptualization: Ramatu Abdullahi Methodology: Ramatu Abdullahi Alice Jonah, Henrietta Ayakpat Manuscript: Ramatu Abdullahi, Attahiru Abubakar Data Analysis: Ramatu Abdullahi, Jabiru Garba, Rufai Abutu Review Writing: Alice Jonah, Henrietta Ayakpat, Josephine Abedo, Rakiya Abdullahi, Hafsah, Muhammad

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