Original Article

SEASONAL PATTERNS AND TRANSMISSION RISK OF *Simulium* SPECIES (BLACKFLIES) IN KAGARKO LOCAL GOVERNMENT AREA OF KADUNA STATE NIGERIA.

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ABSTRACT

Blackflies and onchocerciasis are still an important problem to health and agriculture in developing countries including Nigeria. This study was thus aimed at carrying out an entomological assessment of the transmission of Onchocerca species by blackflies in Kagarko Local Government Area of Kaduna State. Blackflies were collected through the Human Landing Catch (HLC) method between 7:00 am – 5:50 pm over a twelve-month period (July 2019 – June 2020). The blackflies were identified using morphotaxonomic characters. Dissections were done to determine parity of the blackflies. Infection rates were determined through further dissections of the abdomen, thorax and head. Transmission indices were determined through specific formulae. A total of 3512 adult Simulium damnosum were caught on HLC. Temperature and relative humidity were recorded using the whirling hygrometer. 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 the dry season. The savannah species of blackflies was significantly more abundant than the forest species ($p < 0.05$). Out of the 779 dissected blackflies, 73.68% were parous. Parity rates between rainy season and dry season differed significantly ($p<0.05$). Three flies were found to be infected with microfilaria during the study period. Prevalence of infection in July and August was 3.846% and 0.53% respectively. Annual Biting Rates (ABR) was estimated to be 35,907 Bites/Person/Year and Annual Transmission Potential (ATP) was estimated to be 231.33 L3/Person/ Year which by far exceeds WHO standards of the ABR of 1000 Bites/Person/Year and ATP of 100 L3/Person/Year as tolerable values for a person living in a highly endemic zone and receiving treatment. Monthly Biting Rates (MBR) and Monthly Parous Biting Rates (MPBR) differed significantly ($p < 0.05$). From these results, the study area still remains endemic to blackflies and onchocerciasis transmission despite interventions implying that interventions have not been fully effective in order to achieve complete elimination of the disease.

KEYWORDS: Simulium, Onchocerca, Onchocerciasis, Abundance

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INTRODUCTION

Blackflies (Diptera: Simuliidae) are insects of veterinary and medical importance found around fast flowing well oxygenated water bodies. Onchocerciasis is transmitted by a complex of species (*Simulium damnosum S.l*). Nine sibling species of *S. damnosum* complex taxonomically identified and documented include *S.sirbanum, S.damnosum s.s, S.dieguerense, S. sanctipauli, S.soubrense, S.squamosum, S.yahense, S.leonense and S.konkorense* (Mafuyai *et al.,* 1996, Takaoka, 2001). Entomological studies have shown that six out of the cytological species are found in Nigeria and are involved in disease transmission (Anong *et al*., 2015). Blackflies (Diptera: Simuliidae) are aggressive blood-feeders on humans, domestic livestock and a variety of warm-blooded wildlife. These flies which breed in most river systems are the vectors of the filarial worm known scientifically as *Onchocerca volvulus.* Blackflies in Nigeria, are endemic across 32 states including the Federal Capital Territory. In Nigeria, and across the globe, new endemic foci of blackfly and onchocerciasis are frequently discovered. Nwoke, *et al.*, (1998) reported that blackflies are widespread in Katsina Ala River in Benue state, Kaduna River in Kaduna state, Anambra River in Anambra and Kogi states, Oji River in Enugu and Anambra states, Imo River in Imo state. Others include Abia and Rivers States, Cross Rivers, Akwa Ibom states among others. In monitoring transmission of onchocerciasis, surveillance of infectivity status of *Simulium* along river systems plays an important role. In Tanzania, Hendy *et al*., (2018) recorded infectivity rate of 0.57% in a study conducted in the Mahenge Valley. In Nigeria, studies have recorded infectivity rates of 36.75% along river Kaduna in Kaduna state, 28.70% along river Muvur in Adamawa state, and 0.2% along Ogun and Yewa rivers in the South Western region of the country (Maikaje *et al*, 2015, Bichi and Inuwa, 2010, Wobo *et al*, 2013). Such studies are important epidemiological tools as they could be the first step in early detection of transmission thus giving an insight into the prevention and control strategy to be adopted in an area. Onchocerciasis which is the second leading cause of infectious blindness, affects up to 50% of adults in endemic communities. In Nigeria, the incidence of *Simulium* constitutes a threat to the affected areas as the fear of blindness and biting menace of the flies, results in 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. Furthermore, the morbidity from this disease results in decreased worker productivity. Onchocerciasis is both a public health hazard and a socio-economic problem of great magnitude in Nigeria often referred to as a disease of 'the poor' Prevalence of onchocerciasis is directly related to the abundance of blackfly. An understanding of transmission dynamics of onchocerciasis is important in advancing knowledge on how vector competence, behavior and abundance influence level of infection and disease in susceptible human populations. Capture and dissection of adult flies can be used as a means of following the dynamics of a *Simulium* population and vector infectivity and thus the level and magnitude of parasitic transmission. Different infectivity rates can be found at different sites and it is recognized that different cytospecies of *S. damnosum* complex living in different biotypes may carry heavier *O. volvulus* infective worm loads than others. Transmission of disease relies on vectorial competence or capacity. When the prevalence and intensity of Infection in the flies are combined with the density of the vectors biting humans in a particular

locality, it is possible to estimate the intensity of transmission, which is an important risk factor. Vectorial capacity is a parameter which expresses the intensity of disease transmission in a particular space and season. Vector density, vector competence and vector survival are all important components of vectorial capacity. Differences in vector competence, which might be influenced by the existence of *Onchocerca-Simulium* complexes, could potentially affect transmission in areas where the cytoform composition is not stable. Vectorial capacity is determined through dissection of which some figures must be determined to help assess the level of transmission (Lamberton *et al*., 2014). However, the intensity of onchocerciasis transmission is generally estimated by measuring the Annual Biting Rate (ABR) that is the number of bites potentially received by a person greatly exposed in a given locality. The Annual Infective Biting Rate (AIBR) is as the Annual Biting Rate but calculated with the proportion of biting blackflies harboring infective larvae. The Annual Transmission Potential (ATP) is the average number of infective larvae potentially received by a maximally exposed person in a given location (Botto *et al*., 2013; Monsuru *et al*., 2010; WHO, 2002). The quantitative entomologic study was conducted to obtain data that can be used in monitoring and evaluation of the trends of *S. damnosum* infection.

MATERIALS AND METHODS

Study Area

The study was carried out along the Gurara river system between latitude 9^0 15N and longitude 7^0 15E 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 Gurara village is between Latitude 9^0 66N and longitude 7^0 88E. It has considerable river valleys and farmlands as well as rocky topography. 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 majorly koro, Jaba and some Fulani settlers. Kaduna state shares borders with Niger, Zamfara, Katsina, Kano, Plateau and Nassarawa States.

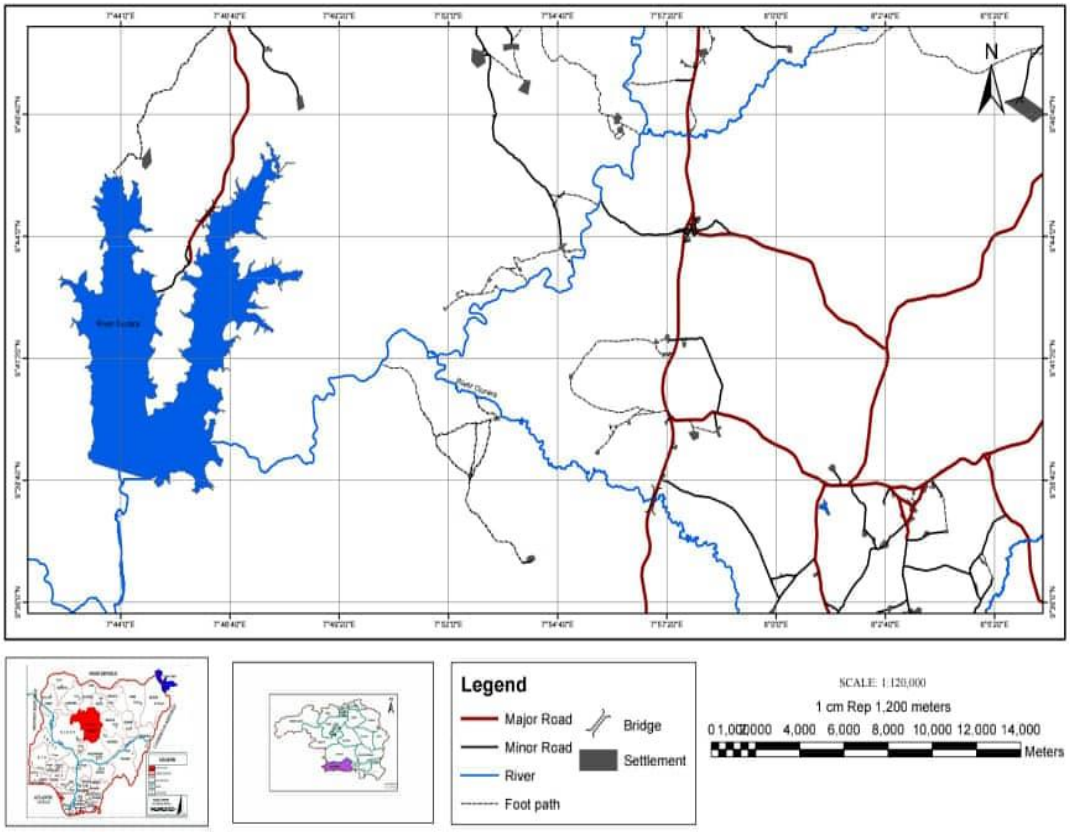


Fig 1. Map of the Study Area Showing the Gurara River System

Ethical Statement

A letter of 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 and after collections.

Collection of Blackflies

Collection of blackflies was carried out over a period of twelve months from July 2019 to June 2020 covering both the wet and dry season. Adult blackflies were collected from the Gurara River banks for three consecutive days in a week in every month of collection (Lamberton *et al.*, 2014, Nascimento-Carvalho *et al.*, 2017). Collections were from three sampling points which were along the river banks. 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, 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 a 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. in the morning and in the afternoon between 1:00 p.m. - 5:50 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.

Morphological Identification of Caught *Simulium*

The blackflies captured, were immediately identified morphologically on the field with the aid of a field dissecting microscope in two steps. The first step was by morphologically identifying each caught fly by individually anaesthetizing them using chloroform vapor then placing on a microscope slide with a drop of saline solution and identified by noting features such as the humped back thorax, wings, mouthparts and the frons as described by Takaoka (2001). The second step was by morphologically identifying the blackfly species by using morphotaxonomic characters such as the color of wing tufts, post cranial hairs; color of fore coxa and the ninth abdominal segment (Oluwole *et al*., 2009). Adult blackflies were morphologically identified as either savannah dwelling species or forest dwelling species (Garms, 1978, Wilson *et al*., 1994; Offor, 1999; Takaoka, 2001; Iboh and Arong, 2015; Chikezie *et al.,* 2015). Those with pale features were classified as the savannah species (*S. damnosum s.s* and *S. sirbanum*) while those with dark features were classified as the forest dwelling species (*S. squamosum, S yahense*) (Offor, 1999, Oluwole *et al.*, 2009).

Determination of Transmission Potentials of Female *Simulium*

Following morphological identification, the blackflies were dissected to determine parity. The disease transmission potentials of female *Simulium* caught was determined through parous examinations (Lamberton *et al.,* 2014). Using fine needles, the abdomen was slit down the lateral surface and the ovaries separated from the other viscera. The flies were identified as either parous or nulliparous. Flies with transparent malphigian tubules with absence of or having few fat bodies were classified as parous flies while flies with unclear malphigian tubules and presence of fat bodies were classified as nulliparous flies (Wobo *et al* 2013).

Determination of Infection Rates in *Simulium* and Transmission Indices

Further dissection of the abdomen, thorax and head was continued if the fly was found to be parous to check for the presence of filarial worms (Opara *et al.,* 2005; Lamberton *et al.,* 2014). Using dissecting pins, presence of *Onchocerca* larvae was determined by separating the head from the thorax and teasing it out. Any L3 (Infective) larvae were readily visible and usually separated itself from the debris by slow movement. The numbers of parasites were counted and recorded (Nelson and Pester, 1982). Larvae found in the thorax (L2 Preinfective) and abdomen (L1 Sausage shape) were also counted and recorded. Where it was not possible to dissect all flies, they were brought back to the laboratory alive in collection tubes with soaked cotton wool placed on ice packs in cold boxes (Atting *et al.,* 2005). Infection rate was calculated as a percentage (%) of microfilaria in blackflies caught. Annual Biting Rate (ABR) was calculated as the sum total of the Monthly Biting Rates (MBR) established for each month of capture (Opara *et al.,* 2008). Annual Transmission Potentials (ATP) was calculated as the sum total of the Monthly Transmission Potentials (MTP) for each month of capture (Lamberton *et al.,* 2014, Opara *et al.,* 2005).

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 Chi^2 analysis was applied to determine the association between variables. (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 between July 2019 to June 2020. Figure 1 illustrates the variations in the abundance of blackflies as well as the relative humidity and temperatures recorded. The mean temperature and relative humidity during the study period was 27.19^0c and 85.80% respectively. The highest number of blackflies caught was in the month of August with 1002 (28.5%) of the total flies caught. Relative humidity and temperatures were 89% and 26^0c respectively. This was followed by July with 887 (25.3%) of the total catches. Relative humidity and temperatures were 93% and 24^0c respectively. In September, 777 (22%) of the total caught flies was recorded while the relative humidity and temperature were recorded as 73% and 27^0c. The least number of black flies were however caught in the months of January with only a single fly catch (0.03%) and December where 3 flies were caught (0.09%). Relative humidity and temperatures in December and January were recorded as 5%, 13.3^0c and 4%, 13.6^0c in that order.

The Pearson correlation analysis (r) examined the relationship between 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 in 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 in 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). Table 1. shows that seasonal blackfly abundance was higher in the rainy season (93.4%) than the dry season (6.5%). Conversely, the savannah species morphologically identified was 3491 (99.4%) while the forest species was 21 (0.6%). The chi^2 test (x^2) showed that the savannah species was significantly more abundant than the forest species caught (x^2 = 3.512.000, p = 0.000).

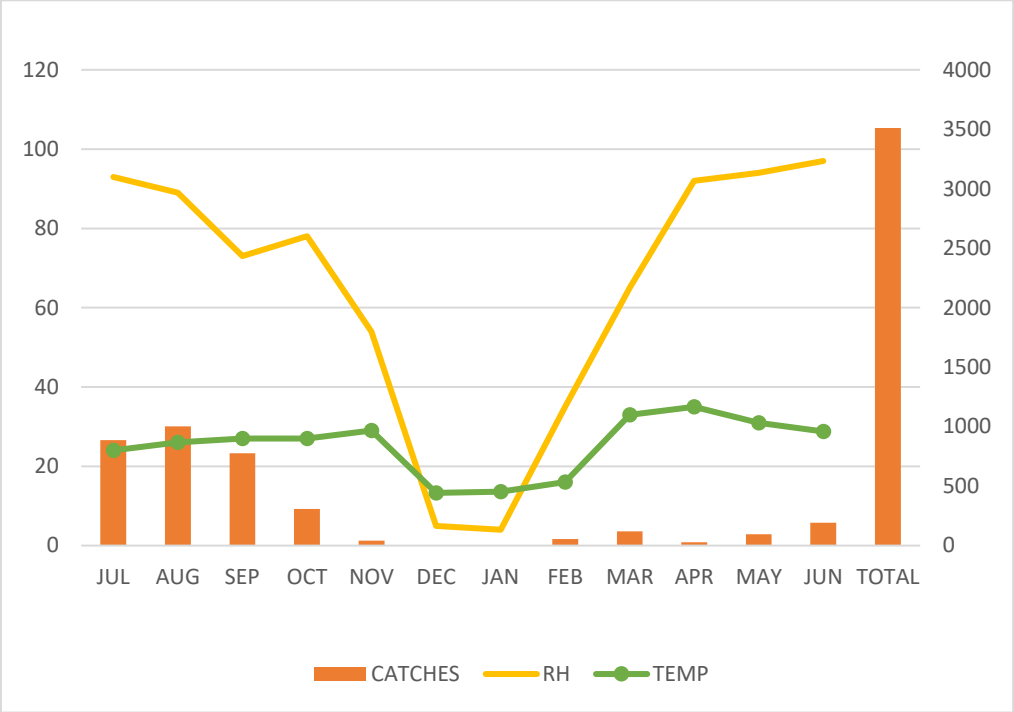


***Figure 1**. Abundance of Caught Blackflies and Weather Data in Gurara River Recorded July 2019 – June 2020*

Table 1: Seasonal Variation in the Abundance and Species of Caught Blackflies Morphologically Identified at the Gurara River July 2019 – June 2020

Season	Savannah (%)	Forest (%)	Total (%)	x^2 (*p*- value)
Rainy	3262(92.9)	21 (0.6)	3283 (93.4)	
Dry	229 (6.5)	0 (0.0)	229 (6.5)	
Total (%)	**3491 (99.4)**	**21 (0.6)**	**3512(100)**	**3512.000* (*p* = 0.000)**

Table 2 illustrates that out of the 3512 sampled blackflies, 779 (22.2%) were dissected for parity rates. The total number of blackflies dissected during the rainy season were 676 (86.77%) while 103 (13.22%) were dissected during the dry season. Overall, 205 (26.31 %) of the flies were found to be nulliparous while 574 (73.68%) were parous flies. However, during the rainy season, a total of 168 (24.85%) were nulliparous while 508 (75.15%) were parous flies while in the dry season, 37 (35.92%) were nulliparous while 66 (64.07%) were parous flies. The chi^2 test of significance showed that the parity rates of the dissected blackflies between the rainy season and dry season was significant (x^2 = 5.649, p = 0.017).

Table 2: Parity Rates of Dissected Blackflies Caught at the Gurara River July 2019 – June 2020

Season	Nulliparous (%)	Parous (%)	Total (%)	x^2	*p* value
Rainy	168 (24.85)	508 (75.15)	676 (86.77)		
Dry	37 (35.92)	66 (64.07)	103 (13.22)		
Total (%)	**205 (26.31)**	**574 (73.68)**	**779 (100)**	**5.649**	**0.017**

The results of the microscopic examination of the dissected blackflies are presented in table 3. Out of the 779 blackflies dissected, 3 were infected with microfilaria. Infections

were found only in the months of July and August. In July, prevalence of infection was 3.846% while in August prevalence of infection was 0.53%. No infection was further recorded throughout the rest of the months of the study.

Table 3: Prevalence of Infection (PoI) in Blackflies Sampled Monthly at the Gurara River during the Study Period July 2019 – June 2020

Months	**No Dissected**	**Number Positive**	**%**
July	52	2	3.8
August	188	1	0.5
September	246	0	0
October	75	0	0
November	20	0	0
December	3	0	0
January	1	0	0
February	29	0	0
March	37	0	0
April	13	0	0
May	27	0	0
June	88	0	0
Total %)	779 (22.2)	3	

Table 4. establishes that the concentrations of microfilaria found in the anatomical parts of the flies were in the Head (H) and the Thorax (T). No mf was found in the Abdomen (A) throughout the study. However, 2 flies were positive with infections within the thorax. Conversely, a single infection was found within the head of the dissected blackflies. No fly however, had all the three larval stages within it.

Table 4: Microfilaria at the Different Anatomical Parts of Blackflies Sampled July 2019 – June 2020

	Number Positive	percentage positive	x^2	*p* value
Head	1	0.1	0.348	0.555
Thorax	2	0.3	0.697	0.404
Abdomen	0	0		
Total (%)	3	0.4		

The summary of the biting rates and transmission indices of the caught blackflies is shown in table 5. Monthly Biting Rates (MBRs) ranged from 10 to 10,354 Bites/Person/Month. The highest MBR was recorded in the month of August with 10,354 Bites/Person/Month while the least biting rate was recorded in January, with 10.33 Bites/Person/Month. Monthly Transmission Potentials (MTPs) ranged from 0 to 176 L3/Person/Month. MTP was recorded only in July and August with monthly MTPs of 176 and 55.1 L3/Person/Month respectively. No MTP was recorded throughout the other months of the study. Monthly Parous Biting Rates (MPBRs) ranged from zero in January with 2040 being the highest recorded in September. Monthly infective Biting Rates (MIBRs) of 10.33 each was recorded in July and August while zero MIBR was recorded throughout the rest of the months of the study. Annual Biting Rates (ABR*) and Annual Transmission Potentials (ATP**) were estimated to be 35,905 Bites/Person/Year and 231.1 L3/Person/Year respectively. The differences between the

monthly MBR and MPBR was statistically significant ($t = 2.240$, $p = 0.036$).

Table 5: Biting Densities and Transmission Indices of Simulium during the Study Period July 2019 – June 2020

MONTH	MBR	MTP	MPBR	MIBR
July	9166	176	258.3	10.33
August	10354	55.1	1457	10.33
September	7770	0	2040	0
October	3183	0	651	0
November	420	0	110	0
December	31	0	10.33	0
January	10.33	0	0	0
February	541.3	0	213	0
March	1240	0	258	0
April	280	0	70	0
May	981.66	0	134	0
June	1930	0	610	0
TOTAL	*35907	**231.1	5811.63	20.66

*ABR = Sum of all MBR **ATP = Sum of all MTP **p* value 0.036

DISCUSSION

This study revealed the presence of black flies along the Gurara River and 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, low turbidity which form favorable breeding sites for blackflies are found along the Gurara river banks (Mafuyai *et al*., 1996). Rocky basements and submerged substrata that provide support for aquatic stages of insects such as blackflies are also found along the Gurara river banks.

The monthly and seasonal relative abundance of blackflies within this study shows that more savannah species (99.4%) were caught than the forest species (0.6%). The abundance of the savannah dwelling species is however not an unexpected outcome since Gurara river is located in the Northern Guinea savannah region of Northern Nigeria. It is a known fact that the savannah dwelling species of *S. damnosum S.I* are found in the savannah zone and the forest species are confined to the forest areas (WHO, 1995).The findings within this study is supportive of earlier observations that the distribution of *S. damnosum S.l* is to a great extent related to the bioclimatic zones of which ecology plays a major role (Crosskey, 1959, Adeleke *et al*, 2010, Onojafe *et al* 2020, Busari *et al* 2021). The pockets of the forest species found however, may be as a result of migration either from returning farmers or cattle herders from the forest region of the country where the forest species are in abundance (Wilson *et al*, 2002). Having knowledge of the type of species of blackflies found in an area is important as it has been established that the savannah species are the transmitters of the more virulent strain of the parasite/disease (resulting in ocular morbidity) than the forest species that transmit the benign form of the disease. Likewise, knowledge of the type of onchocerciasis prevalent in any bioclimatic zone is dependent on the taxonomy of the vectors and the parasite strain of the vectors (Iboh *et al*, 2015, Onyenwe *et al* 2017, Toe, 1997). The morphological method of identification employed within this study however did not

differentiate definitely which specie of the blackflies was which. Earlier reports however have shown that morphological identifications can distinguish into savannah group consisting of *S. damnosum s.s*, *S.sirbanum*, and *S. dieguerense* or the forest group consisting of *S.sqamosum*, *S.yahense* and *S. sanctipauli* with other eight species. Oluwasegun (2018) posited that the old and practical procedure of morphological identifications available to distinguish between the species of adult female *S.damnosum* complex still remains the assessment of micro-morphological characters. Using morphological characters have shown that *S.yahense* can be identified with 99% precision (Oluwasegun 2018). Several previous studies on morphological characters of *S.damnosum* complex revealed that the savannah cytospecies could be easily separated from the forest dwelling species using the color of the wing tufts, fore coxa and the abdominal tergites as was done in this study. A high proportion of the flies dissected were parous and there was a significant seasonal difference in the parity of the flies during the study period (p = 0.017). During the rainy season, 75.15% of the flies were found to be parous while 24.8% were nulliparous. (Table 2). These observations are similar to earlier published reports (Okolo *et al*., 2004, Opara *et al* 2005, Adeleke *et al*., 2011, Mose *et al*., 2020) although refutes Onah (2020) where majority of the flies recorded were nulliparous in a study conducted in the Obinna River in Adani in Enugu state Nigeria, Lamberton *et al* (2014) in a study conducted in Ghana, Akinsanya *et al* (2019) at the Owena dam and Busari *et al* (2021) at the Owena River in Osun state Nigeria. Having a preponderance of parous flies is suggestive that majority of the flies are older flies. Having older population of blackflies in an area increases the probability of having mature parasites within the vector; thus poses a high risk of being infected with the disease as only parous flies can transmit the disease since a fly must take a bloodmeal to be exposed to the parasite. Parous vectors often show that it has fed at least once from a host. The parous rate of man biting *S. damnosum* is often greater in savannah areas of West Africa than the Forest areas. Dissection of *S. damnosum* in Sudan – Savannah areas of Cameroon indicated that nulliparous flies dispersed mainly inland away from larval habitats whereas, parous flies especially the older ones tended to stay closer to riverine vegetation. The high proportion of the parous flies observed in the flies dissected within the study could be an indication of high fly-man contact as a result of the activities of the people within the study area who by and large engage in farming, fishing, cattle rearing and other agricultural practices. The high proportion of parous females also indicates aging of the local black fly population which may reflect successful larviciding or the presence of migratory females. The presence of nulliparous females on the other hand, indicates incomplete vector control, probably resulting from an absence or deficiencies in larviciding or the colonization of untreated tributaries. In addition, the more parous blackflies found in a population, the more the longevity of the vector also increases (Kaola *et al*., 2019, Mose *et al*, 2020). Blackflies are known as long distance migrants hence the nulliparous flies caught may be from migration (Adeleke *et al* 2011). Having knowledge on high parous rates and peak biting time, provides useful information on the design of entomological evaluation protocols for the monitoring of onchocerciasis vector control and onchocerciasis elimination programs (Mose *et al*, 2020).

The result of dissection of this study shows that there are still preinfective and infective flies at the Gurara River system.

Infection and infectivity rates were established within this study. The presence of microfilariae in the dissected flies during the study period indicates some level of risk of onchocerciasis transmission. This has been supported by Isiaku (2014) in a previous study along the Gurara River. Although the total dissected flies in this study were not up to the required 1/2000 flies threshold used by the Onchocerciasis Control Program as an indicator for the interruption of disease transmission, some possible factors that could account for the transmission level recorded are perhaps low levels of microfilaria (mf) in human hosts, which reduces the vectorial potential of the *Simulium* vectors as the flies need to ingest reasonably high number of microfilariae to ensure continuous transmission of infection (Higazi *et al*, 2013, Ojurongbe *et al*, 2015). Edoh (2004) however, has contrary views to this as was posited that uptake of *Onchocerca volvulus* is not dependent on the density of skin microfilariae in human host. Numbers of surviving mf in the flies, and the survival rate of the flies (as it is almost impossible to find mf within a dead fly microscopically) are other probable factors. It has been observed that few out of hundreds of mf ingested by the flies usually survive the effects of the peritrophic membrane that is secreted by the female fly after blood meals (Edoh *et al*, 2004). The level of infectivity of the flies within the study may equally be attributed to low mf loads in the human reservoirs due to ivermectin as residents in the study area indicated that they have been receiving ivermectin for the treatment of onchocerciasis annually (Osue *et al* 2013). Finding low levels of mf especially in areas where ivermectin is being distributed has been supported in other reports (Katabarwa *et al*., 2016, Eisenbarth, *et al* 2016). Diawara (2009) posited that in endemic communities in Mali and Senegal there is a possibility of elimination of onchocerciasis through several treatments with ivermectin since treatment lowers the parasite load. Another point to note is that although the method of determining the prevalence of flies carrying infective larvae has for long been through field dissection of captured flies, this method suffers the disadvantage of the fact that *S. damnosun S.I* also serves as the vector of zoonotic species of *Onchocerca* that do not affect man. For example, *O.ochengi*, a bovine parasite, causes bovine onchocerciasis found in West Africa (Unnasch *et al* 2018). The larvae of these animal parasites are difficult or even impossible to distinguish morphologically from *O. volvulus* thus dissection data can result in over estimation of the intensity of transmission (Rodriguez-Perez *et al* 2015). An assured way of distinguishing between these two parasites is through the PCR technique which distinguishes *O. volvulus* from other *Onchocerca* present in *S. damnosum* (Doyle *et al* 2016, Unnasch *et al* 2018). A seasonal variation in the MBR and MTP was observed within the study. However, no transmission took place except during the rainy season between July and August (Table 5). Transmission, measured by MIBR in July and August could be partly attributed to the higher number of flies present during these months and as such, leading to increased anthropophilly of the flies (Cheke *et al* 1992, Ubachukwu & Anya 2005). The overall minimal levels of MTP and MIBR recorded within the study conversely, may be as a result of some control measures in place (Such as ivermectin distribution). Zero MTP and MIBR recorded during the dry season could be ascribed to some variations in human behavior as there are lesser activities that take place by the river side and also lesser number of flies available hence translating into reduced vector-man contact and by extension, reduced transmission of disease.

The Onchocerciasis Control Program in West Africa and WHO, considers an Annual Biting Rate (ABR) of 1000 Bites/Person/Year and an Annual Transmission Potential of 100 infective larvae per year as tolerable values for a person living in a highly hyperendemic zone and receiving treatment (Opara *et al*, 2005, Opara *et al*, 2008, Adewale *et al* 1999, Kaola *et al* 2019). The ABR and ATP values recorded in this study exceed these values indicating transmission of onchocerciasis (despite the ongoing treatment with ivermectin within the study area as earlier pointed out). The value of ABR recorded during the study period by far exceeds the limits set by the OCP for the interruption of disease transmission hence considered for onchocerciasis transmission by the WHO. The high biting rates of the flies recorded during the months of the rainy season are of high risk to the residents as this is a hint of a high vector - man contact within the area. This poses a threat to agricultural production as the biting nuisance may lead to abandonment of fertile farmlands as well as posing a high risk of disease transmission. Likewise, the migration of infected human hosts with high microfilarial load could affect the transmission of onchocerciasis in the area since the vectors are available in high abundance. These hosts usually come back to engage in farming activities during the rainy season. These high biting rates pose a biting nuisance and a threat in disease transmission. The biting menace is of socio-economic importance as their painful bites serve in distracting human hosts from their work thus reducing productivity. (The women have to wear long trousers even at home to prevent the flies from biting so that they can concentrate in carrying out their daily chores). The bites also serve as a mechanical entry point for other pathogens which the flies may carry (Terungwa, 2018). In view of the above, in order to control both vector and parasite, it is advised that an integrated approach should be considered especially as frequent treatment with ivermectin decreases the parasite load by reducing the prolificacy of the female adult *O. volvulus* worms.

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REFERENCES

Adeleke, M. A., Mafiana, C. F., Sam-Wobo, S. O., Olatunde, G. O., Ekpo, U. F. and Akinwale, O. P. (2010). Biting behaviour of *Simulium damnosum* complex and *Onchocerca volvulus* infection along Osun River, Southwest Nigeria. *Parasites and Vectors* 3(93): 1-5.

Adeleke, M. A., Sam-wobo, S. O., Olatunde, G. O., Akinwale, O. P., Ekpo, U. F. and Mafiana, C. F. (2011). Bioecology of *Simulium damnosum* Theobald complex along Osun River, Southwest Nigeria. *Journal of Rural and Tropical Public Health* 10: 39-43.

Adewale, B., Mafe, M.A., and Oyerinde, J.P.O (1999). Infectivity and Transmission Dynamics of *S. damnosum S.I* around Owena Dam (Ondo State). *West African Journal of Medicine. 18:257-260.*

Akinsanya, B., Adewale, B., Adenusi, A., Lawal, A.D., Rahman, O (2019). Infectivity of *Simulium damnosum S.I* and therapeutic coverage of Ivermectin distribution 10 years post Treatment around Owena dam, Ondo state, Nigeria. *The Brazilian Journal of infectious Diseases* 23 (6):410 – 410.

Anbalagan, S., Prasanna, V.A., Dinakaran,S., and Krishna, M (2013). Molecular Phylogeny and Vector Potential of Blackflies (Diptera: Simulidae) in India. *International Journal of Advanced Life Sciences* (*IJALS*) Vol (6) Issue (5).

Austen, E. E (1909). *Illustration of African blood sucking flies other than mosquitoes and tsetse flies.* British Museum, London Pp 221.

Atting, I.A., Ejezie, G.C., Braide, E.I., Opara, K.N and Ekwe, A (2005). Seasonal variations in human onchocerciais transmission by blackflies (*Simulium damnosum*) in a forest area of Cross River State, Nigeria. *African Journal of Applied Zoology and Environmental Biology. Vol 7, 14-1*

Bichi, A.H and Inuwa, B (2010) Distribution of *Simulium* species and its infection with *O. volvulus* along river Muvur, Mubi, Adamawa state. *Bayero Journal of Pure and Applied Sciences,* 3(2):91-93.

Busari, L.O., Ojunrongbe, O., Adeleke, M.A., Surakat, O.A., Akindele, A.A (2021).Biting behavior and infectivity of *Simulium damnosum* complex and *Onchocerca* parasite in Alabameta, Osun state, Southwerstern Nigeria. *PLoS ONE 16(6).*

Cheke, R.A., Sowda, S.A., Avissey,H..S.K., Fiasorgbor,G.K.,Garms, R (1992) .Seasonal Variation in Onchocerciasis transmission by *Simulium squamosum* at perennial breeding sites in Togo. *Transactions of the Royal Society of Tropical Medicine and Hygiene 86, 67-71*.

Chikezie, F.M., Ehize, E.K., Uzoigwe, N.R., Opara,K.N., Igbe,M.A., Okonkwo, J.N., Nwakwo,E.N., Nwoke, B.E.B (2015). A concise entomology evaluation of Onchocerciasis Transission in Ahani-Achi community in Oji River Local Government Area of Enugu State, Nigeria. *Int. J. Cur Res Rev* Vol 7. Issue 5 pp 57-58.

Crosskey, R.W (1955). Observations and Bionomics of adult *Simulium damnosum* Theobald (Diptera: Simuliidae) in Northern Nigeria. *Annals of Tropical Medicine and Hygiene* 49,142-153.

Crosskey, R. W (1959). Aspects of blackfly control and entomology in the new world in relation to *Simulium* problem in Nigeria. *Bulletin of World Health Organization* 21,727-736.

Crosskey, R. W (1990). The Natural History of blackflies. *Chichester. John Wiley & sons.* Pp 711.

Dalil, M., Mairabo, A.P., Hussaini, A., Babangida, U.M., Abubakar, A (2015). Impact of Gurara Dam on land cover in the surrounding communities of Kaduna State, Nigeria. *Journal of Environmental and Eath Science.Vol 5No 16pp27-37.*

Domino, A (2015). Non-Parametric Pairwise Multiple Comparisons in Independent Groups using Dunn's Test. *Stata Journal 15:292 -300*.

Doyle, S.R., Armoo, S., Renz, A., Taylor, M.J., Osei- Ateweneboana, M.Y., Grant, W.N (2016). Discrimination between *Onchocerca volvulus* and *Onchocerca ochengi* filarial larvae in *S. damnosum S.I* and their Distribution throughout Central Ghana using a versatile high resolution speciation Assay. *Parasites and Vectors 9:536.*

Diawara L, Traoré, M. O., Badji, A. (2009). Feasibility of Onchocerciasis Elimination with Ivermectin

Treatment in Endemic foci in Africa: First evidence from studies in Mali and Senegal. *PLoS Negl Trop Dis.* 3 (7).

Edoh, S.A., Basanez, M.G., Bissan, Y., Boatin, B.A., Jan, H.F., Nico, J.D., Devlas, S.J., Gerard, J.J., Habbema, J.D (2004). Uptake of *Oncocerca volvulus* (Nematoda: Onchocercidae) by *Simulium* (Diptera: Simuliidae) is not strongly dependent on the density of skin microfilariae in the human host. *J. Med. Entomol* 41(1):83-94.

Eisenbarth, A., Achukwi, M.D., Renz, A (2016). Ongoing Transmission of *Onchocerca volvulus* after 25 years of Annual Ivermectin Mass Treatments in the Vina du Nord River Valley in North Cameroon. *PLoS Negl. Trop. Dis 10 (2)*

Eyo, E.J., Ikechukwu, E.O., Ubachukwu, P.O., Ivoke, N., Ekeh, F.N (2014). Effects of climatic conditions on the biting density and relative abundance of *Simulium damnosum* complex in a rural Nigerian farm settlement. *Annals of Agricutural and Environmental Medicine vol 21 no 4 697-700*.

Francesca, T., Alice, H., Katrin, G., Achim, H., Eric, P., and Mark, J. T (2011).Onchoceriasis: The Role of *Wolbachia* Bacterial Endosymbionts in parasite biology, disease, and pathogenesis and treatment. *Clin. Microbiol. Rev. Vol 24 no3 459-468*

Garms, R (1978). Use of morphological characters in the study of *Simulium damnosum S.l* populations in West Africa. *Tropen med Parasitol* 29:483-491.

Garms, R., Badu, K., Owusu-Dabo, E., Baffour- Awualu, S., Adjei, O., Debrah, A.Y., Nagel, M., Biritwum, N.K., Gankpala,L., Post, R.J., Kruppa, T.F (2015). Assessments of the transmission of *Onchocerca volvulus* by *Simulium sanctipauli* in the upper Denkyira District, Ghana and the intermittent disappearance of the vector. *Parasitol Res* 114:1129-1137.

Grillet, M.E., Maria-Gloria., Vivas-Martinez, S., Nestor, V., Hortensia, F., Jose, C., Pablo, C and Carlos, B (2001). Human onchocerciasis in the Amazonian area of southern Venezuela: Spatial and temporal variations in biting and parity rates of blackflies (Diptera: Simuliidae) vectors. *Journal of Medical Entomology*,38(4):520-530.

Hendy, (2018). Blackfly ecology and *Onchocerca volvulus* transmission in three formerly hyperendemic foci in Uganda, Tanzania and Cameroon. *PhD Thesis Institute of Tropical Medicine Antwerp.*

Higazi, T.B., Zarrough, I.M.A., Mohammed, H.A., Elmubark, W.A., Deran, T.C., Aziz,N., Katabarwa, M., Hassan, H,K., Unnasch, T.R., Mackenzie,C.D (2013). Interuption of *Onchocerca volvulus* transmission in the Abu Hameed focus Sudan. *Am.J. Trop.Med. Hyg* 89(1) pp 51-57.

Iboh, C.I and Arong, G.A (2015). Morphological studies of female *Simulium damnosumS.l* in Akamkpa Local Government Area, Cross River state, Nigeria. *International Journal of Entomology and Nematology* 2(1):002-008.

Isiaku, S (2014). Effects of long term community Treatmrnt with Ivermectin on *Onchocerca volvulus* Infections in Humans and the *Simulium damnosum* vector in parts of Kaduna State. *PhD Thesis Ahmadu Bello University Zaria, Nigeria.*

Kaola, L., Nikiema, A. S., Para, A.B., Drabe, F., Toe, L.D., Belem, A.M.G., Boakye, D.A., Traore, S., Dabire, R.K (2019). Entomological Assessment of the Transmission following Recrudescence of Onchocerciasis in the Comeo Valley Burkina Faso. *Parasites and Vectors 12(34) pp 2-9.*

Katabarwa, M.N., Eyamba, A., Nwane, P., Enyong, P., Kamgno, J., Kuete, T., Yaya, S., Aboutou, R., Mukenge, L., Kfando, C., Siaka, C., Mkpouwouelko, S., Ngangue, D., Biholong, B.D., Andze, G., (2013). Fifteen Years of Annual Mass Treatment of Onchocerciasis with Ivermectin have not Interrupted Transmission in the West Region of Cameroon. *Journal of Parasitology Research. ID420928.*

Katholi C.R., and Unnasch, T.R (2006).Important Experimental Parameters for Determining Infection Rates in Arthropod Vectors using Pool Screen Approaches. *Am. J. Trop. Med. Hyg. 74:779-785.*

Katholi, C.R (2010). Poolscreen v2.0 University of Alabama. *Http://www.Soph. uab.edu/bst/poolscreen.*

Lamberton, P.H., Robert, A.C., Martin, W., Peter, Mike, Y.O., Inaki, T., Anthony, T., Daniel, A.B., Michael, D.W., Rory, J.P and Maria, G.B (2014). Onchocerciasis transmission in Ghana: Biting and Parous Rates of Host Seeking Sibling Species of the *Simulium damnosum* complex. *Parasites and Vectors* 7:511.

Mario, R., Bruce, G. L., Alfredo, D., Christian, L., Alberto, M., and Thomas, R. U. (2004).Polymerase Chain Reaction Monitoring of Transmission of *Onchocerca volvulus* in two endemic States in Mexico. *Am. J. Trop. Med. Hyg* 38–45.

Mafuyai, H.B., Post, R.J., Vajime, C.G., Molyneux,D.H (1996). Cytotaxonomic identification of The *Simulium damnosum* Complex (Diptera: Simuliidae) from Nigeria. *Tropical Medicine International Health* 1 (6): 779- 785.

Maikaje, D.B., Dibal, D.M., Umar, Y.A., and Egbe, N. E (2015). Investigations on the transmission potentials of *Simulium damnosum* and the risk of human onchocerciasis in Kaduna metropolis, Kaduna State Nigeria. *Journal of Public Health and Epidemiology* Vol 7(7), pp 217-222.

Meredith, S. E.O., Lando, G., Gbakima, A. A., Zimmerman, P. A. and Unnasch, T. R. (1991).*Onchocerca volvulus*: Application of the Polymerase Chain Reaction to Identification and Strain differentiation of the Parasite. *Experimental Parasitology*, 73:335-344.

Mose, A.D., Behailu, T.M and Solomon, Y (2020). Monthly dynamics and Biting behavior of principal Onchocerciasis vector (*Simulium damnosum S.I*) in Endemic area of South West Ethiopia. *Int. J. One Health* 6(1):23-27.

Mukhtar, B. F (2003). *An Introduction to Biostatistics.* 1st Edition. Samarid Publishers. ISBN 9783543288.

Nnadozie, R.I.A., Onyewe, E., Ibeduegha, B.N., Okorie, A.G (2018). Entomological evaluation by dissection of adult *Simulium damnosum* complex for larvae of *O. volvulus* following CDTI in Amagu Agba community Ishielu LGA Ebonyi state, Nigeria. *America Journal of Public Health Research Vol 6 no 226-30.*

Nascimento-Carvalho, E.S.D., Cesario, R.D.A., Do Vale, V.F., Aranda, A.T., Valente, A.C.D., Maia-Herzog, M (2017). A new methodology for sampling blackflies for the entomological surveillance of onchocerciasis in Brazil. *PLoS ONE* 12(17): e0179754.

Nelson, G. S and Pester, F.R. N (1982). The identification of infective filarial larvae in Simuliidae. *Annals of Tropical Medicine and Parasitology.* 27:473.

Nwoke, B. E, Dozie, N. S., Gemade, E.I I., Jiya, J.Y (1998). The present status of human onchocerciasis in South Eastern Nigeria using Rapid Epidemiological Mapping of onchocerciasis (REMO). *Nigerian Journal of Parasitology* vol 19 pp11-18.

Ochu, J.C., Umeh, E.N., Njom, V.S (2021). Identification of the sibling species of blackfly *Simulium damnosum* complex using their polytene chromososmal banding patterns in Oji River system, Enugu State Nigeria. *African Journal of Biology and Medical Research. Vol 4 Issue 3 pp 69-78.*

Offor, I.I (1999). Review of the Current Status of Morphotaxonomy in the Characterization and Identification of *Simulium damnosum* Theobald Complex (Diptera:Simuliidae). *Nigerian Journal of Entomology. 16: 50-58*

Ojurongbe, O., Akindele, A.A., Adeleke, M.A., Oyedeji, M.O., Adedokun, S.A., Ojo, J.F (2015). Coendemicity of Loiasis and Onchocerciasis in Rain Forest Communities in Southwestern Nigeria *PLoS Negl. Trop. Dis 9(3).*

Oluwasegun, N.A (2018). Molecular Characterization of *Simulium damnosum* Complex in an Endemic Focus of Gurara River, Kagarko Local Government of Kaduna State Nigeria. *MSc Dessertation Ahmadu Bello University Zaria Nigeria.*

Onojafe, O.J., Egwunyenga, A.O., Ighere, J.E (2020). Spatio-Temporal Distribution of Two Cyto-species of Adult Host- seeking blackfly (*Simulium damnosum*) in Delta State, Nigeria. *American Journal of Zoology 3(4):78-83.*

Osue, H.O., Inabo, H.I., Yakubu, S.E., Audu, P.A., Galadima, M., Odama, L.E., Musa, D., Ado, S.A., and Mamman, M (2013). Impact of eighteen-year varied compliance to onchocerciasis Treatment with Ivermectin in Sentinel Savannah Agrarian Communities in Kaduna State of Nigeria. *ISRN Parasitology* vol

Ogunrinade, A. D.,Boakye, A., Merriweather, T., and Unnasch. (1999). Distribution of the Blinding and Non-Blinding Strains of *Onchocerca volvulus* in Nigeria. *The Journal of Infectious diseases,* 179: 1577-1579.

Okolo, C. G, Dallah C. N, Okonkwo, P.O (2004). Clinical manifestation of onchocerciasis and some aspects of its control in Achi, Oji River L.G.A, Enugu State Nigeria. *Nigerian Journal of. Parasitology* 25: 101-106.

Oluwole, A.S., Ekpo, U.F., Mafiana, C.F., Adeojun, C.O., Idowu, O.A (2009). Preliminary Study of Temporal Variations in Biting Activity of *Simulium damnosum* in Abeokuta North LGA, Ogun State Nigeria. *Parasites and Vectors 2:55*.

Onah, I.E., Ubachukwu, P.Oand Eyo, J.E (2020). Status of *Onchocerca*

volvulus infection and Transmission by blackflies after 15 years of Ivermectin distribution at Adani, Nigeria. *Tropical Biomedicine* 37 (1):174-185.

Opara, K.N., Fagbemi, O.B., Ekwe, A., and Okenu, D.M (2005). Status of forest Onchocerciasis In the lower cross river basin Nigeria. Entomologic profile after five years of Ivermectin Intervention. *Am. J. Trop. Med. Hyg* 73(2) pp 371-376.

Opara, K.N., Usip, L.P., and Akpabio, E.E (2008). Transmission Dynamics of *Simulium damnosum* in Rural Communities of Akwa Ibom State, Nigeria. *J. Vector Borne Dis 45 pp225-230.*

Py-Daniel and Medeiros. F (2004) Seasonality Parity Rates and Transmission Indices of *Mansonella azzardi* (Manson) (Nematoda: Onchocercidae) by *Cerqueirellum argentiscutum* (Shelly and Luna Dias) (Diptera: Simuliidae) in a lower solimoes river community. Amazonas, Brazil. *Acta Amazonica* 34(2):1-10.

Rodriguez-Perez, M.A., Fernandoz-Santos, N.A., Orozo-Algarro, M.E., Rodriguez-Atanaccio, J.A., Dominguez-Vasquez, A., Rodriguez-Motales, K.B (2015). Elimination of Onchcerciasis from Mexico. *PLoS Negl. Trop. Dis. 9 (7) pp1-15.*

Rodriguez, P.M.A., Davies-Lozano, R., Rodriguez, M.H., Unnasch, T.R., Bradley, J.E (1999). Detection of Onchocerca volvulus infection in *Simulium ochraceum S.I* Comparison of a Polymerase Chain Reaction Assay and Fly Dissection in a Mexican Hypoendemic Community *Parasitol 119:613-619.*

Service, M. W (1977). Methods for sampling adult Simuliidae, with special reference to the *Simulium damnosum* complex. *Tropical Pest Bulletin (5) Center for Overseas Research, London, UK.*

Service, M.W (1980). A guide to Medical Entomology 3rd Edition. *Blackwell Scientific Publishers pp 95-101.*

Sileshi, G (2007). A method for estimating the insect abundance and patch occupancy with Potential Applications in Large Scale Monitoring Programs. *African Entomology 15(11): 89-101.*

Taye, A., Gebre-Michael, T, Staticheff, S (2000). Onchocerciasis in Gilgel Ghibe River valley Southwest Ethiopia. *East African Medical Journal 77(2):116-120.*

Takaoka, H (2001). *Simulium Weji sp. nov.* (Diptera: *Simuliidae*) from Thailand. *Jpn. J. Trop. Med. Hyg. 29: 349–354.*

Terungwa, U.C (2018). Environmental Conditions Favouring Growth of Blackfly in Ikov Ward of Ushongo Local Government Area of Benue State Nigeria. *International Journal of Education and Reaserch. Vol 6 no 5 pp175-188.*

Toe, L., Tang, J., Back, C., Katholi , C.R., Unnasch, T.R (1997). Vector Parasite Transmission Complexes for Onchocerciasis in West Africa. *The Lancet vol 349 pp163-166.*

Unnasch, T.R and Meredith, S.E.O (1996). The use of Degenerative Primers in Conjunction with strain species oligonucleotides to classify *Onchocerca volvulus*. Clapp JP. ed. *Methods in Molecular Biology vol 50 Species Diagnostics Protocol PCR and other nucleic Acid Methods. Totowa,NJ:Humana press, Inc,293-303.*

Ubachukwu, P.O and Anya, A., (2005). Seasonal variations in the biting

densities of *Simulium damnosum* Complex (Diptera: *simuliidae*) in Enugu State, Nigeria. Implications for Farmers. *Journal of Agriculture, Food, Environmental and Extension vol 4 no 1 pp10-13.*

Unnasch, T.R (2011). Complete Protocol for O- 150 PCR Analysis of Blackflies for *O. volvulus* Infection. *Protocol Adopted for African Blackflies.*

Unnasch, T.R., Golden, A., Cama, V.,Cantey, T.P (2018). Diagnostics for Onchocerciasis in the era of Elimination. *The Royal Society of Tropical Medicine and Hygiene 10:120-126.*

Wilson, M.D., Mafuyai, H.B., Post, R.J (1994). Morphological Identification of Sibling Species of the *Simulium damnosum* (Diptera: Simulidae) Complex from Nigeria, Cameroon, and Bioko. *Proc.Exper. & Appl.Entomol., Nev. Amsterdam, Vol.5 pp 181-186.*

Wilson, M.D., Cheke, R.A., Flasse,S.P.J., Grist,, S., Osei- Ateweneboana, M.Y., Atteh-Kumah., Fiasorgbor, G.K., Jolliffe, F.R., Boakye,D.A., Hougard, J.M., Yameogo, M., Post, R.J (2002). Deforestation and the spatio-temporal distribution of savannah and forest members of *Simulium damnosum* Complex in South Ghana and Southwestern Togo. *Transactions of the Royal Society of Tropical Medicine and Hygiene 96,632-639.*

Wilson, A.L., Courtenary, O., Kelly-Hope, L.A., Scott, T.W., Takken,W., Torr,S.J., Lindsay, S.W (2020).The importance of vector control for the control and elimination of vector-borne diseases. *PLoS Neglected Trop Dis 14(1).*

World Health Organization (1991). *Simulium* – Vectors of Onchocerciasis. *Advanced Level Training and Information Guide.* WHO/VBC/91.992.

World Health Organization (1995). Onchocerciasis and its Control. Report of a WHO expert Committee on onchocerciasis Control. *World Health Organization Technical Report series No 852.*

World Health Organization (2002) Training Manual for Entomology Technicians in charge of entomological activities in Onchocerciasis control. 388/01/VCU/ADM/15.2

Wobo, O.S., Monsuru, A, Jayeola, O.A., Amazigo, U. V (2013). Seasonal Fluctuations of *Simulium damnosum* Complex and *Onchocerca* Microfilarial Evaluation in River Systems, Southwest Nigeria. *International Journal of Tropical Insect Science 33(01).*

Yameogo, L., Toe, L., Hougard, J., Boatin, B.A., Unnasch, T. R (1999). Pool Screen Polymerase Chain Reaction for Estimating the Presence of *Onchocerca volvulus* Infection in *Simulium damnosum sensu lato*: Results of a Field Trial in an Area Subject to Successful Vector Control. *Am. J Trop. Hyg. 60(1) pp 124-128.*

Zarrough, I. M. A., Hashim, K., Elaagip, A.H., Samy, A.M., Frah, E.A., Elmubarak, W.A., Mohammed, H.A., Deran, T.C.M., Aziz, N., Higazi, T.B (2016). Seasonal Variation in Biting Rates of *Simulium damnosum S.I.* Vector of *Onchocerca volvulus* in two Sudanese foci *PLoS One 11 (3) eo150309.doi10.137*