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Effects of climatic conditions on the biting density and relative abundance of *Simulium damnosum* complex in a rural Nigerian farm settlement

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Abstract

Introduction and objective. The effect of climatic conditions on the biting density and relative abundance of *Simulium damnosum* complex at Adani, Nigeria, from August 2010 – January 2011 was investigated.

Materials and methods: The classical method of collecting blackflies for a period of 11 hours using human attractants was employed in the study. Monthly climatic data, such as rainfall, relative humidity and temperature were collected for the period of study.

Results. Rainfall, relative humidity, temperature, harmattan (cold, dry wind) and deforestation were observed to affect the biting density and relative abundance of blackflies at the site. A total of 548 female adult blackflies were collected. The biting density of the flies ranged from 0.5 Flies/Man/Hour (FMH) in December to 5.5 FMH in January. The relative abundance of the flies ranged from 21 in December to 243 in January. Regression analysis showed that temperature and relative humidity had a positive correlation with relative abundance of *Simulium damnosum* complex ($y = -0.0006x + 25.593$, $r = 0.0519$) and ($y = -0.1213x + 78.794$, $r = 0.505$), respectively.

Conclusions. The risk of getting infected with *Onchocerca volvulus* increased during the dry season with its associated weather conditions.

Key words

Simulium damnosum, biting density, relative abundance, climatic variables

INTRODUCTION

In many sub-Saharan African countries, onchocerciasis caused by the filarial nematode *Onchocerca volvulus* is a chronic parasitic infection with public health and socio-economic consequences of considerable magnitude [1, 2]. It is an insect-borne disease transmitted by the *Simulium damnosum* Theobald complex in West Africa [3]. Onchocerciasis affects about 17 – 18 million people in 37 countries worldwide, with approximately 123 million being at risk of infection [4]. In Nigeria, onchocerciasis is widespread and a cause of blindness in most rural communities.

In Nigeria, *O. volvulus* is transmitted primarily by the *S. damnosum* complex [5]. Cytotaxonomic studies of the *S. damnosum* complex from different parts of Nigeria have revealed the presence of 5 cytospecies: *S. damnosum* sensu stricto, *S. sirbanum*, *S. squamosum*, *S. yahense* and *S. soubrense* [6]. The prevalence of human onchocerciasis has been observed to be directly related to the presence and abundance of its vector, *S. damnosum* complex [2, 7]. The abundance and distribution of the vector *S. damnosum* complex, in turn, is determined by climatic conditions.

Bodenheimer [8] was the first to suggest that the population density of the insect is regulated primarily by the effect of weather. According to him, weather affects both the development and survival of the insect. Insects are cold-blooded organisms – the temperature of their bodies is approximately the same as that of the environment; therefore, temperature is probably the single most important environmental factor influencing insect behaviour, distribution, development, survival and reproduction [9]. Some researchers believe that the effect of temperature on insects largely overwhelms the effect of other environmental factors [10]. Other researchers have found that moisture and carbon dioxide effect on insects can be potentially important considerations in a global climate change setting [11, 12, 13].

The major diseases that are most sensitive to climate change are vector-borne diseases [14]. According to Patz et al. change in weather and climate that can affect transmission of vector-borne diseases includes temperature, rainfall, wind, extreme flooding or drought, and rise in sea level [15]. Each species of vector has characteristic climatic requirements; some are sensitive to increases in temperature, others are not. Most of the endemic vector-borne diseases are tropical and hence global warming will potentially increase the range of this vector [16].

Ikpeama et al. emphasized that the pattern and intensity of the host-seeking activity of haematophagus insect was a function of many interacting biological and physical factors, such as abundance, physiological ages, host factors, light, temperature, humidity and atmospheric pressure [17]. In Okigwe in Imo State, Nigeria they observed that *Simulium*

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damnosum bite more when there was a wind than when there was no wind. However, they noted that factors such as water level, rain, bush burning, height of growing vegetation, as well as wind direction, may affect the biting densities of *Simulium damnosum* complex.

According to Gubler et al., weather and climate affect vectors in several ways. Temperature can decrease or increase the survival of vectors, depending on the species; changes occur in the following:
– rate of vector population growth;
– feeding rate and host contact;
– seasonality of populations;
– transmission season;
– distribution [18].

According to Gubler et al., increase in rain may increase larval habitat and vector population size by creating a new habitat; excess rain or snow pack can eliminate habitat by flooding, thus decreasing the vector population size; increase humidity increases vector survival; decreased humidity decreases vector survival.

An understanding of the effect of change in climatic conditions on the biting density and relative abundance of *S. damnosum* complex in any particular climatic zone will be of immense benefit in vector monitoring and onchocerciasis surveillance and control, which constitutes a vital contribution to global public health security.

Objective. The aim of the presented study was to investigate the effects of climatic conditions on the biting frequency and relative abundance of blackflies *Simulium damnosum* complex in a rural Nigerian agricultural settlement (Adani) between August 2010 – January 2011.

MATERIALS AND METHOD

Study area. The study area was Adani in Uzo-Uwani Local Government Area of Enugu State, Nigeria. Coordinates: 6°43'60" N and 7°1'0" E in DMS (Degrees Minutes Seconds) or 6.73333 and 7.01667 (in decimal degrees) (Fig. 1). UTM position: KN84, Joint Operation Graphics reference – NB32–05. Current local time is 09:29; sunrise – 08:10, sunset – 20:17 local time (Africa/Lagos UTC/GMT+1). The standard time zone for Adani is UTC/GMT+1. The approximate population of Adani for 7 km radius from this point is 17,992. The mean annual temperature in Adani is 22.5^{0}C [19]. The people are primarily farmers, being famous forn rice and cassava production. Crop production is all year round in irrigated farmlands.

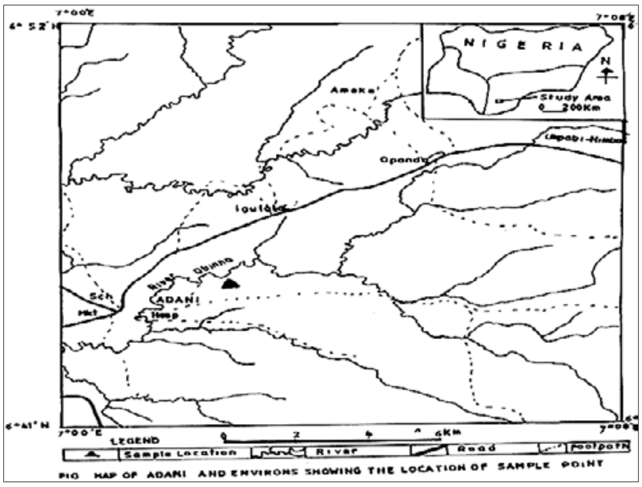

Figure 1. Map of Adani in Uzo-Uwani Local Government Area of Enugu State, Nigeria, showing sampling location (▲)

Ethical approval. The subjects used for baiting were recruited after thorough explanation of the details of the study protocol, and their voluntary written consent was obtained. The study was approved by the University of Nigeria Teaching Hospital (UNTH) Research Ethics Committee.

Method of catching Blackfly. Biting adult female *Simulium damnosum* complex were collected using human bait [2, 5, 20, 21]. A sampling point located approximately 300 metres from Obina River at Adani was used as the fly collection site. The site was sampled 4 times a month from August 2010 – January 2011. Fly catching was conducted from 07.00 – to 18:00 (11 hours) by 2 fly collectors who worked alternate hours [6, 22, 23]. The collectors sat on a stool in the forest with their feet and the legs below the knees exposed. Any fly that perched on the exposed parts was collected before it started feeding by inverting a small glass tube over it, and the cap replaced immediately. The tubes containing the flies were labelled to indicate time and date of collection, and the total number of flies caught per day was recorded.

Climatological data. Monthly average temperature, rainfall and relative humidity of the study area were calculated from daily weather data collected by the Meteorological Station at the Federal Ministry of Agriculture at Adani in Uzo-Uwani Local Government Area of Enugu State, Nigeria, and used to determine their influence on the biting density and relative abundance of *S. damnosum* complex.

Statistical analysis. The data collected were subjected to analysis of variance (ANOVA). F-LSD was used to compare significance differences in the biting peaks for the different months. Regression and correlation analyses were used to establish the relationship between the climatic data and the number of flies caught in the different months.

RESULTS

Relative abundance and biting density of flies at Adani. A total of 548 *S. damnosum* complex were caught at the site. Of this number, 248 were caught in the rainy season (August, September and October), while 300 were caught in the dry season (November, December and January). The highest number of flies was caught in January 2011 (243 flies), while the least number in December 2010 (21 flies). The monthly biting density of the flies ranged from 0.5FMH in December to 5.5FMH in January (Tab. 1). The monthly variation in the relative abundance and biting density of *S. damnosum* complex indicated that the monthly catches between September – October; and between December – January were significantly different ($p < 0.05$). However, the monthly catches between August – September; October – November; and November – December were not significantly different ($p > 0.05$) (Tab. 1).

Table 1. Relative abundance and biting density of *Simulium damnosun* complex at Adani, August 2010 – January 2011

Months	Total No. of flies caught	Biting density (FMH)	Monthly average rainfall (mm)	Monthly average temper-ature (°C)	Monthly average relative humidity (%)
August	69	1.60	12.34	24.27	83.59
September	136	3.10	12.48	24.42	82.75
October	43	1.00	4.87	25.31	79.87
November	36	0.80	0.59	26.52	75.20
December	21	0.50	0.00	26.45	49.68
January	243	5.50	0.01	26.24	35.20

Influence of climatic conditions on relative abundance and biting density of *Simulium damnosum*. An inverse significant relationship exists between the relative abundance and biting density of *Simulium damnosum* complex and rainfall. High rainfall in August (12.43 mm) corresponded with a low relative abundance of *S. damnosum* (69 flies). On the other hand, a high temperature in January (26.24 °C) correlated with a high relative abundance of *S. damnosum* (243.00 flies), while high relative humidity in August (83.59) corresponded with low relative abundance of *S. damnosum* (69.00 flies). Regression analysis revealed that both temperature and relative humidity had a positive correlation with the number of flies caught ($y=-0.0006x+25.593$; $r=0.0519$) and ($y=-0.1213x+78.794$; $r=0.505$), respectively, while rainfall had a negative correlation with the number of flies caught (Tab. 2).

Table 2. Relationship between temperature, rainfall and relative humidity with abundance and biting density of *Simulium damnosun* complex at Adani, August 2010 – January 2011

Parameters	Mean	Regression Equation	R	P-value
Abundance	91.33 + 34.57	0	0	0
Temperature	25.535 + 0.416	y = -0.0006x + 25.593	0.0519	0.011005
Rainfall	5.048 + 2.44	y = 0.0004x + 5.0093	-0.0223	0.000146
Humidity	67.715 + 8.29	y = -0.1213x + 78.794	0.505	0.003132

Diurnal biting pattern of flies at Adani. The diurnal biting patterns of *S. damnosum* complex at Adani showed a bi-modal peak of activity, with the evening peak being higher than the morning peak, except in October when the morning peak was higher than the evening peak. The peaks were separated by hours of low biting intensity. The morning peaks were observed between 07.00 – 09.00 in October, 08.00 – 09.00 in August and November, and 09.00 – 10.00 in September, December and January. The evening peaks were observed between 17.00 – 18.00 in August, December and January, while in November and September it occurred between 16.00 – 17.00 pm. However, in October, the evening peak was observed between 16.00 – 18.00. A paired t-test treatment of the mean biting peaks in all the months showed that the morning and evening biting peaks were not significantly different ($P > 0.05$).

DISCUSSION

The progressive decrease in fly relative abundance from September – December was in agreement with the findings of previous studies from the tropics [2, 5, 6]. The study recorded the highest number of flies in January, which was in agreement with the findings of Ubachukwu and Anya [24] who observed a similar increase in fly population in Nkpologu, Uzo-Uwani Local Government Area of Enugu State during the dry season with the cold, dry wind (harmmattan). The observed decrease in fly population at Adani from September – October may be attributed to continuous flooding of the river during the peak rainy season (August, September and October), which may have resulted in the dislodging and washing- away of immature stages of *Simulium* flies to long distances away from Adani. In addition, an earlier report suggested that rainfall increases relative humidity and lowers temperature, thus negatively affecting fly biting activity [25].

According to Opara et al., stormy weather may be a factor because it may have washed-away most of the breeding sites, thus resulting in a smaller fly population [2]. Also, Atting et al. noted that the Kwa fall in southern Nigeria which was completely flooded in the month of October 1999, resulted in the dislodging and washing-away of immature stages of *Simulium* flies [6]. They argued that the flooding brought about reduced productivity of existing breeding sites during the rainy season, hence decreasing the fly population in that month. Ikpeama et al. reported that during the months of heavy rain, the water level rises, thereby slowing the water velocity considerably, and consequently rendering water bodies unsuitable for the breeding of *Simulium* species [17]. They also attributed the gradual decrease in the population of blackflies during the rainy season to the dislodgment of *Simulium* larvae from their habitats, increased flooding effect, and increased density of predators [17]. According, flies were extremely scarce during the rainy season, resulting in their low relative abundance and consequent low biting densities [17, 25].

The observed reduction in the abundance of flies during the months of November and December may be attributed to the extensive bush burning that occurred all through those 2 months that could have led to massive death and migration of the adult flies. Taye et al. attributed the decline in the population of *S. neavei* and *S. ethiopiense* in Ethiopia to degradation of vegetation cover in the vicinity of their breeding sites [20]. Also, McMahon et al. noted that deforestation was the sole means used to eradicate *S. neavei* s.s. and onchocerciasis from some foci in Kenya [26]. In addition, bush burning and deforestation releases carbon dioxide into the lower atmosphere, thereby causing global warming; hence, the mean temperature reached its peak in these months with the fly biting density and relative abundance being lowest. This contradict the report by Ikpeama et al. who reported that blackflies prefer a higher temperature, which is consistent with other haematophagus insects, [17] but is in agreement with Nwoke et al. who observed that a very high temperature negatively affects the biting of *Simulium damnosum* complex [25].

The month of January was characterized by very low rainfall (mean 0.01mm) low relative humidity (mean 35.20%), mean temperature of 26.24°C and the harmattan wind; biting density of the flies reached maximum (5.5 FMH). The observed high fly density during the harmattan may lie, in addition to local flies, of migrating savanna flies carried down into the area with the help of the north-south harmattan winds blowing from the Sahara to the coasts [27]. The possible addition of these migrating flies to the local flies during the harmattan would most likely be responsible for swelling the biting populations of the blackflies during this period [28]. At Adani, the Obina River flows perennially, thus, *S. damnosum* complex is assumed to breed throughout the year; hence, the observed sudden increase in fly population density in the month of January 2011 (harmattan) may be attributed to flies that were carried by wind from other breeding sites, in addition to local production of flies, plus flies that migrated from other breeding sites where the river/stream dried-up. In the Okigwe area of Imo State, Ikpeama et al. observed that there were more biting flies when there is a wind than when there was no wind [17].

The diurnal biting pattern of the flies showed a bi-modal peak of activity – a morning peak and a more pronounced evening peak – in all the months except October when the morning peak was higher than the evening peak. These findings were in agreement with reports from earlier studies in the tropics [2, 5, 23, 24], but contradicted the report of Adeleke et al. who observed 3 biting peaks in 2 different sampling points in south-western Nigeria [29], and Barbiero and Trpis who observed a uni-modal biting peak activity pattern in Liberia [30].

The biting density of flies at Adani ranged from 0.5 FMH in December to 5.5 FMH in January. The biting density of flies recorded at Adani is far below the maximum range given by Crosskey who stated that in Africa the highest biting rate of *S. damnosum* complex were usually not above 30–60 FMH in Savanna, and 200 FMH in forest areas, whereas biting densities of 100–1000 FMH are commonplace with *S. ochraceum* complex in Guatemala and 300–450 FMH typical of *S. oyapockense* in the Amazon [31]. Opara et al. recorded biting densities of 27.7 FMH, 35.8 FMH and 33.5 FMH in 3 different sampling points in Akwa Ibom State, Nigeria [5]. In their earlier study, biting densities of 0.5 FMH in December and 21.6 FMH in August were reported for Cross River State, Nigeria [2].

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REFERENCES

1. Moyou-Somo R, Eyong PA, Fobi G, Dinya JS, Lafleur C, Agnamey P, Ngosso A, Mpoudi NE. A study on onchocerciasis with severe skin and eye lesions in a hyperendemic zone in the forest of South Western Cameroon. Clinical parasitologic and entomologic findings. Am J Trop Med Hyg. 1993; 48: 14–19.
2. Opara KN, Fagbemi OB, Ekwe A, Okenu DMN. Status of forest onchocerciasis in the lower Cross River Basin, Nigeria: Entomological profile after five years of ivermectin intervention. Am J Trop Med Hyg. 2005; 73(2): 371–376.
3. Ibe OO, Nwoke BEB, Adegoke JA, Mafuyai HB. Cytospecies identification of vectors of human onchocerciasis in south eastern Nigeria. Afr J Biotech. 2006; 5: 1813–1818.
4. WHO. Conquering suffering enriching humanity. WHO Report, Geneva, 1997.
5. Opara KN, Usip LP, Akpabio EE. Transmission dynamics of *Simulium damnosum* in rural communities of Akwa Ibom State, Nigeria. J Vector Borne Dis. 2008; 45: 225–230.
6. Atting AI, Ejezie GC, Braide EI, Opara KN, Ekwe A. Seasonal variations in human onchocerciasis transmission by blackflies (*Simulium damnosum s.l.)* in a forest area of Cross River State, Nigeria. Afr J App Zool Environ Biol. 2005; 7: 14–18.
7. Crosskey RW. A review of *Simulium damnosum s. l.* and human onchocerciasis in Nigeria with special reference to geographical distribution and development of a Nigerian National Control Campaign. Tropenmed Parasitol. 1981; 32(1): 2–16.
8. Bodenheimer FS. *Gesduchte der Entomologie.* Berlin, W. Junk, 1928.
9. Curtis P, Seaman A. Climate change effects on insects and pathogens http://www.climateandfarming.org/pdfs/FactSheets/III.2Insects.Pathogens.pdf (access: 2011.11.24).
10. Bale JS, Masters GJ, Hodkinson ID, Awmack C, Bezemer TM, Brown VK, et al. Herbivory in global climate change research: direct effects of rising temperatures on insect herbivores. Glo Cha Biol. 2002; 8: 1–16.
11. Coviella C, Trumble J. Effects of elevated atmospheric carbon dioxide on insect-plant interactions. Conserv Biol. 1999; 13: 700–712.
12. Hunter MD. Effects of elevated atmospheric carbon dioxide on insect-plant interactions. Agric Forest Entomol. 2001; 3: 153–159.
13. Hamilton JG, Dermody O, Aldea M, Zangerl AR, Rogers A, Berenbaum MR, et al. Anthropogenic changes in tropospheric composition increase susceptibility of soybean to insect herbivory. Environ Entomol. 2005; 34(2): 479–485.
14. WHO. Chikungunya in Kerala due to climate change. http://www.thaindian.com (access: 2011.07.13).
15. Patz AJ, Olson SH, Uejio CK, Gibbs HK. Disease emergence from global climate and land use change. Med Clin J N Am. 2008; 92: 1473–1491.
16. Sutherst R. Global change and human vulnerability to vector-borne diseases. Clin Microbiol Rev. 2004; 17(1): 136–173.
17. Ikpeama CA, Nwoke BEB, Anosike JC, Orji NM, Onyirioha CU. Studies on the biting behaviours of female *Similium damnosum* complex in some endemic areas of Imo State, Nigeria. Inter-Wld J SciTech. 2007; 3: 1–15.
18. Gubler DJ, Reiter P, Ebi KL, Yap W, Nasci R, Patz JA. Climate variability and change in the United States: potential impacts on vector- and rodent-borne diseases. Environ Health Persp. 2001; 109: 223–233.
19. Google Earth. Adani, Nigeria Page. http://www.fallingrain.com/world/NI/47/ Adani.html (access: 2010.09.16).
20. Taye A, Gebre-Michael T, Staticheff S. Onchocerciasis in Gilgel Ghibe River Valley Southwest Ethiopia. East Afr Med J. 2000; 77(2): 116–120.
21. Grillet ME, Maria-Gloria B, Vivas-Martinez S, Nestor V, Hortensia F, Jose C, et al. Human onchocerciasis in the Amazonian Area of Southern Venezuela: Spatial and temporal variations in biting and parity rates of Blackflies (Diptera: Simuliidae) vectors. J Med Entomol. 2001; 38(4): 520–530.
22. Walsh JF, Davies JB, Le Berre R, Garms R. Standardization of criteria for assessing the effect of *Simulium* control in Onchocerciasis Control Programme. Trans R Soc Trop Med Hyg. 1978; 72: 675–676.
23. Opoku AA. Some observations on the ecology, biting activity and parasite infectivity of the blackfly (Simuliidae) and onchocerciasis prevalence in the River Birim Catchments. Ghana J Sci. 2000; 40: 65–73.
24. Ubachukwu PO, Anya AO. Studies on the diurnal biting activity pattern of simulium damnosum complex (Diptera: simuliidae) in Uzo Uwani Local Government Area of Enugu State, Nigeria. Nigerian J Parasitol. 2001; 22(1, 2): 163–168.
25. Nwoke BEB. Studies on the field epidemiology of human onchocerciasis on the Jos Plateau, Nigeria. VII. The effect of climatic factors on the diurnal biting behaviour of *Simulium.* Insect Sci Appl. 1988; 9(3): 323–328.
26. McMahon JP, Highton RB, Goiny H. The eradication of *Simulium neavei* from Kenya. Bull Wld Health Org. 1958; 19: 75–76.
27. Boakye DA, Insecticide Resistance in the *Simulium damnosum* s.l. vectors of Human Onchocerciasis: Distributional, Cytotaxonomic and Genetic Studies. Post-Doctoral Thesis, Netherlands, University of Lieden, 1999.pp.1–194.
28. Ubachukwu PO, Anya AO. Seasonal variations in the biting densities of *Simulium damnosum* complex (Diptera: Simuliidae) in Enugu state, Nigeria: Implication for farmers. J Agric Food Environ Ext. 2005; 6(1): 10–13.
29. Adeleke MA, Mafiana CF, Sam-Wobo SO, Olatunde OG, Ekpo UF, Akinwale OP, et al. Biting behaviours of *Simulium damnosum* complex and O*nchocerca volvulus* infection along the Osun River, Southwest Nigeria. Parasit Vectors. 2010; 3: 93–101.
30. Barbiero VK, Trpis M. Transmission of onchocerciasis by local blackflies on the firestone rubber plantation harbel, Liberia. Am J Trop Med Hyg. 1984; 33: 586–594.
31. Crosskey RW. The Natural History of Blackflies. First Edition, New York, John Wiley and Sons, 1990.