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Black flies aggressivity in Kafolo: influence of climatic and environmental factors

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ABSTRACT

Objectives: The objective of this study is to investigate the influence of environmental factors on aggressiveness rate of black flies, vector of *Onchocerca volvius*, the parasite that causes river blindness in Kafolo, a village adjacent to the Comoé River located at the Ivoiro-Burkinabé border.
Methodology and results: The determination of temporal variations in black flies aggressivity was done using standardised captures method on human bait according to protocol developed by WHO/OCP. At the end of each hour of capture, the number of black flies collected was recorded as well as the temperature and relative humidity. The results showed that except for the months of March and April, the daily bite rates of the black flies were above the WHO tolerance level. The highest daily bite rate (126 bpd) was recorded in September. The black flies aggressiveness was highest in the late afternoon in all seasons, particularly in the rainy season, when fieldwork was taking place. It changed constantly and inversely with ambient temperature and inconsistently with relative humidity.
Conclusion and application of results: This study showed the importance of black flies aggressiveness in Kafolo on the one hand, and the influence of climate and environment on this aggressiveness on the other. The results of this study should guide the development of measures to control the bites of black flies for the control of onchocerciasis in the region.
Keywords: Black fly, onchocerciasis, environmental factors, Ivoiro-Burkinabe border.

RÉSUMÉ

Objectifs: L'objectif général de cette étude est d'examiner l'influence des facteurs environnementaux sur le taux d'agressivité des simulies (mouches noires), vecteur d'Onchocerca volvius, le parasite qui cause la cécité des rivières à Kafolo, un village adjacent au fleuve Comoé situé à la frontière Ivoiro-Burkinabé.
Méthodologie et résultats: La détermination des variations temporelles de l'agressivité des mouches noires a été faite en utilisant une méthode de capture standardisée sur des appâts humains selon le protocole développé par l'OMS/OCP. A la fin de chaque heure de capture, le nombre de

mouches noires collectées a été enregistré ainsi que la température et l'humidité relative. Les résultats ont montré qu'à l'exception des mois de mars et avril, les taux de piqûre quotidiens des mouches noires étaient supérieurs au seuil de tolérance de l'OMS. Le taux de piqûre quotidien le plus élevé (126 piqûres/homme/jour) a été enregistré en septembre. L'agressivité des mouches noires était plus élevée en fin d'après-midi, quelle que soit la saison, en particulier pendant la saison des pluies, au moment des travaux de terrain. Elle évoluait constamment et inversement avec la température ambiante et de manière inconstante avec l'humidité relative.
Conclusion et applications des résultats: Cette étude a montré l'importance de l'agressivité simulidiennne à Kafolo d'une part, et d'autre part, l'influence du climat et de l'environnement sur cette agressivité. Les résultats de cette étude devraient guider à l'élaboration de mesures de lutte contre les piqures des simulies pour le contrôle de l'onchocercose dans la région.
Mots clés : Simulie, Onchocercose, facteurs environnementaux, frontière ivoiro-burkinabé.

INTRODUCTION

Onchocerciasis or river blindness is a parasitic dermal endemic caused by a nematode worm, *Onchocerca volvulus*, which occurs in Africa, Latin America and the Arabian Peninsula. Approximately 123 million people are at risk. The fragmented and heterogeneous area of endemicity in Africa lies between the 15th parallel north and the 14th parallel south (Koala, 2019). The parasite is transmitted to humans infected black flies. The larvae of the insect is aquatic and needs fast-flowing waterways for its development. This explains why the disease outbreaks are found along rivers. Adult female of black flies can also be found at varying distances from the watercourses due to their ability to travel several tens of kilometres (within 24 hours). Female hoverflies, bite outside homes from dawn to dusk. The control of onchocerciasis carried out by the WHO/OCP programme has eliminated the risk of transmission of the disease and has significantly reduced black fly aggressivity in all the countries that benefited from the programme. However, since the programme was terminated in 2002, there has been a massive return of black flies in areas near rivers where these vectors have their breeding grounds (Pitroipa X. *et al.*, 2002; Sylla M. *et al.*, 2002). In Côte d'Ivoire, black fly aggression occurs in many areas along waterways (Pitroipa et al, 2002; Sylla M. 2002; Coulibaly. 2007 and Yapi. 2014). This is the case of Kafolo, located in the North-East of Côte d'Ivoire close to the border with Burkina Faso. Indeed, during a pilot study on the Comoé River, in this area, numerous complaints were recorded from various communities living or working near the river, relating to this increasingly increasing black fly aggressivity in the village of Kafalo. Much research had been undertaken to understand the biology and ecology of the black fly. Some of this research has focused on their activities and more specifically on their aggressivity. Indeed, the topic of black fly aggression had been the subject of many studies. Some of these studies were devoted to the search for factors that could influence the dynamics of their population, and hence the aggressiveness the adults of black fly (imagos). From this research, two main groups of factors have been identified: the first is linked to the simuliidae, particularly its intrinsic state, and the second, known as extrinsic factors, including environmental and climatic factors. This article focuses on the second group, with a focus on climatic factors. This study was carried out in 2019 in Kafolo. Close to Comoé rivers aiming to (i) determine the dynamics of black fly aggressivity on humans during all season and (ii) determine the effect of temperature and relative humidity on this aggressivity in the course of a day.

MATERIALS AND METHODS

Study area: Côte d'Ivoire and Burkina Faso are two border countries in West Africa with an area of 322,462 and 274,200 km² respectively. They share a 584 km border. These two countries share a watercourse, the Comoé River. The River has its source in Péni, a town located between Bobo-Dioulasso and Banfora in Burkina Faso. It crosses Côte d'Ivoire from north to south and flows into the Atlantic Ocean near the town of Grand-Bassam, some 40 km east of Abidjan; its mouth is located east of the Ebrié Lagoon. It is 813 kilometres long. The village of Kafolo is located in the Tchologo region, more precisely in the department of Kong in the North-East of Côte d'Ivoire and on the Ivorian-Burkinabe border. It used to belong to the Health District of Ferkessédougou. But since the end of 2019 it has been attached to the health district of Kong. The village of Kafolo is about 700 km from Abidjan and more than 300 km from Bouaké. It is located between 09° 35' 01".9 N and 04° 18' 59".3 W. In this region, the climate is Sudanese with two main seasons. The dry season, which runs from November to April, precedes the rainy season marked by two rainfall maxima, one in August and September. The daily and annual thermal amplitudes are relatively large; the humidity rate is lower than in the south of the country. This area is characterised by the intermittent presence of a cool, dry wind, the harmattan, between December and February. Annual rainfall varies between 1000 mm and 1400 mm. The average rainfall recorded is 1203 mm (Ferkessédougou). The region's vegetation is composed of a mosaic of shrubby or wooded savannah and open forest. The agroforestry parks are composed of fruit trees that are naturally present but have been modified by human activities, such as baobab, néré, shea, mango and cashew. Agriculture is the main activity in Kafolo, followed by fishing and ecotourism. Kafolo is bordered by the Comoé River. The Comoé enters Côte d'Ivoire at Kafolo and drains the Comoé National Park. This river is a suitable place for the development of black flies (Figure 1).

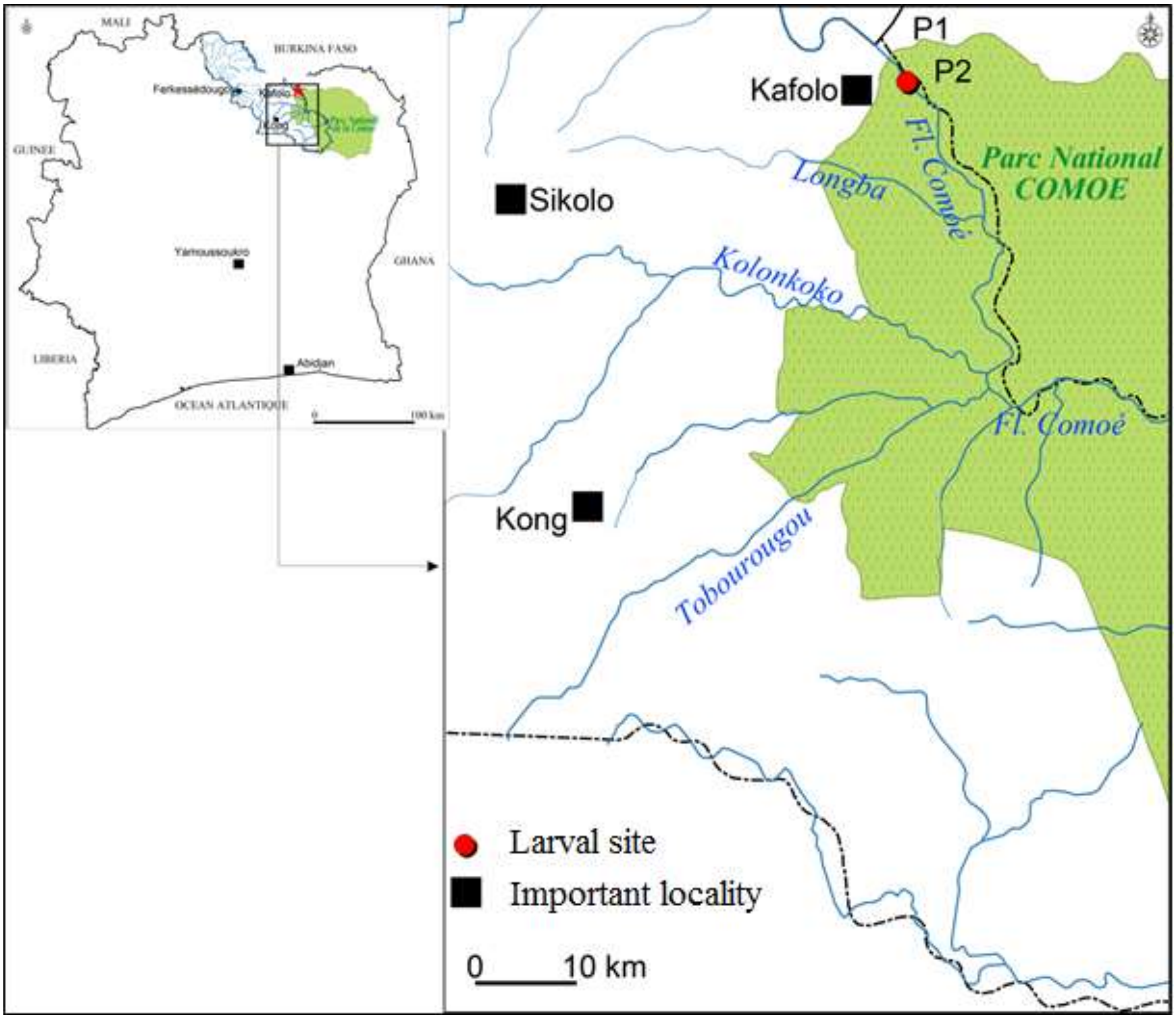

Figure 1: Map of the study area

Methodology: The capture of black flies was done on human bait according to the WHO/OCP capture technique (Berre. 1966; Philippon, 1977). The catchers were previously trained in this technique, treated with ivermectin, and vaccinated against yellow fever according to the recommendations of the National Ethics Committee; some of them received anti-malaria treatment. Within the village, two (02) capture points were chosen according to the selection criteria listed by Le Berre (Le Berre R., 1966) and Philippon (1977 and 1978). The first point is located upstream of the larval site and is called "Kafolo Amont" (09 ° 35 ' 27 ". 9 N and 04 ° 18 ' 36".7 W). The second point named “Kafolo Aval " is located between 09 ° 35 ' 18 " N and 04 ° 18 ' 25". 9 W. The catches were made according to the standard capture mode. This consisted of catching the flies by two catchers on an hourly rotation system. At the end of each hour, the batches were labelled; the date, time, name of the catching point and that of the catcher were specified. The catchers then recorded the number of females caught per hour on a capture sheet, as well as information on meteorological parameters such as ambient air temperature and relative humidity (recorded every hour). The catch was carried out between 7 a.m. and 6 p.m. (i.e. 11 hours); on two consecutive days each month for one year; from January to December 2019. At the end of

this study we determined the following parameters:
-the daily aggressiveness rate or daily bite rate (DBR) or average aggressive density for each month using the following formula

Daily Bite Rate DBR= $\frac{number\ of\ black\ fly\ female\ caught}{number\ of\ catching\ day\ x\ number\ of\ cather}$

-the average monthly temperatures and relative humidity rates by adding up
on the one hand, the sum of the hourly temperatures recorded during the 2 days of monthly capture divided by 22
and the sum of the hourly relative humidity rates recorded during the 2 days of monthly capture divided by 22. NB: 22 represents the total number of hours of capture, i.e., 11 hours of capture in one day during the 2 days in the month.

RESULTS

Seasonal variations in simulidean aggression in Kafolo

Simulidean densities: Table 1 show the number of black flies collected and their aggressivity. A total of 3038 black flies were collected, 1010 in the dry season and 2028 in the rainy season, from January to December 2019. In the rainy season, the average aggressive density recorded was 84.50 bites/person/day with a pick of 126 bites/person/day in September. In the dry season, the average aggressive density was 63.29 bites/person/day, and the lowest were recorded in March and April with a density of 4.5 and 1.5 bites/person/day, respectively.

Table 1: Number of black flies collected and their aggressive densities, data collected from January to December 2019

Seasons	Months	days	Number of black flies caught	Aggressivity (bites/person/day)
Dry season	January	2	281	70,25
	February	2	239	59,75
	March	2	18	4,5
	April	2	6	1,5
	November	2	196	49
	December	2	270	67,5
Total 1			**1010**	**42,08**
Rainy season	May	2	131	32,75
	June	2	219	54,75
	July	2	318	79,5
	August	2	395	98,75
	September	2	504	126
	October	2	461	115,25
Total 2			**2028**	**84,5**
TOTAL			**3038**	**63,29**

Pace of aggression of black flies in Kafolo: The analysis of the hourly aggressiveness of the black flies allows us to note the following points:

During the dry season: A low aggressiveness, very low or even non-existent was recorded during the first hour of catch (7 - 8 hours) from January to March. Thereafter, the aggressiveness of black flies increased progressively during the day, reaching its maximum at the end of the day. However, in March and April, this aggressiveness was not constant throughout the day. There were time slots where it was zero. Two periods of intense aggression were observed: the first between 9 to 11 am and the second much more important at the end of the day, between 4 and 5 pm, (Figure 2).

During the rainy season: In the rainy season, black flies aggressiveness was earlier, i.e., it started earlier in the morning (07:00). The evolution was irregular but important during the day to reach its peak at the last hour of catch (17:00 to 18:00) (Figure 3).

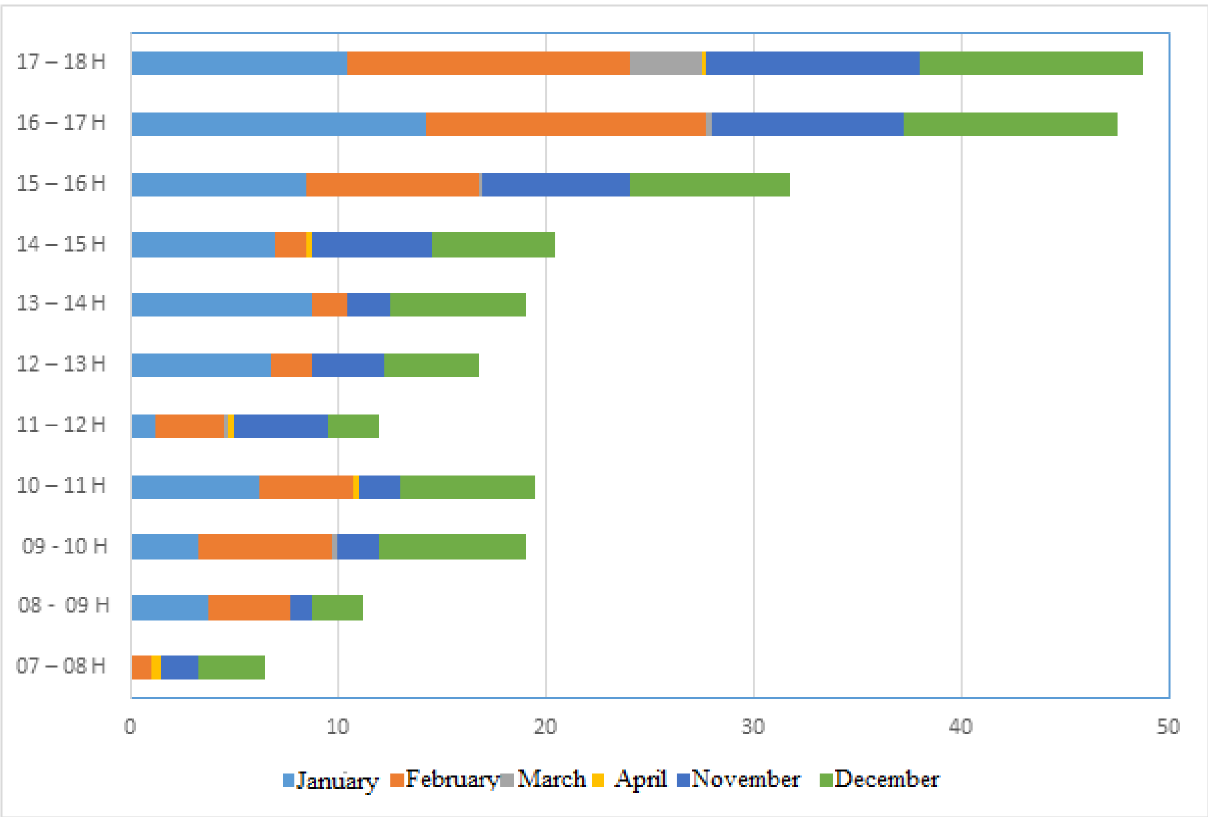

Figure 2: Evolution of the hourly aggressiveness rate of black flies in the dry season

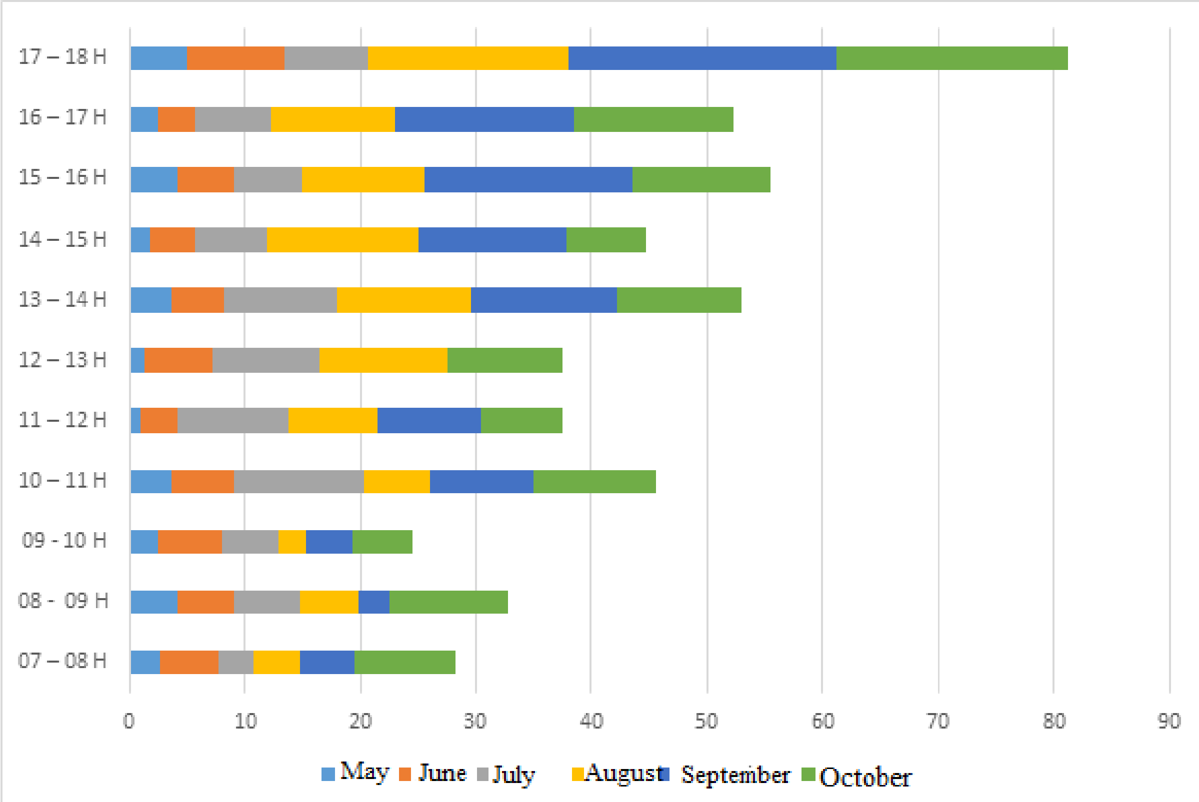

Figure 3: Evolution of the hourly aggression rate of black flies in the rainy season

Effect of temperature and relative humidity on the aggressiveness of black flies: Average temperatures ranged from 26.64°C in January (Harmattan period) to 35.09°C in April. Average relative humidity ranged from 10.09% in April (driest month) to 74.50% in August. During the dry season in March, April and November, the aggressiveness of the black flies evolved in the same direction as the relative humidity and in the opposite direction to the temperature. In fact, during these three months, a decrease in black flies aggressiveness, a decrease in relative humidity and an increase in temperature were noted. In December, black flies aggressiveness gradually increased. The highest rates of aggression in the dry season were observed in December, January and February. Black flies aggressiveness evolved inversely with temperature and also inversely with relative humidity during these 3 months. During the rainy season (May, June, July, August, September and October), black flies aggressiveness evolved in the same direction as relative humidity, in the opposite direction of temperature. Indeed, an increase in black flies um aggressiveness, an increase in relative humidity and a decrease in temperature were noted during the whole rainy season (Figure 4).

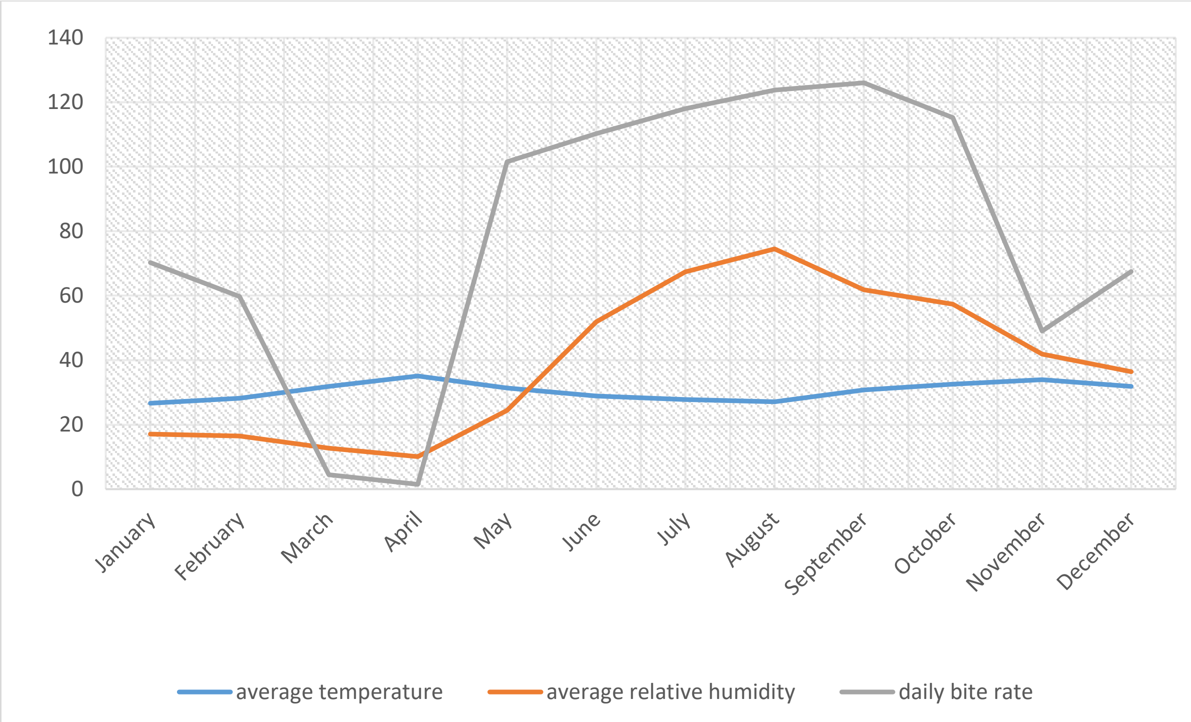

Figure 4: Effect of temperature and relative humidity on the aggressiveness of simuliidae

DISCUSSION

The Comoé River is known to be favourable for the development of black flies. It is a permanent river, whose rugged course offers many possibilities for the installation of preimaginal breeding sites for *S. damnosum* (Le Berre 1966). The Comoé River has an important influence on the transmission of onchocerciasis in this region. Indeed, the seasonal variation in river levels influences the seasonal density of preimaginal populations of *S. damnosum*. The results of the captures indicated that the lowest black flies densities were observed during the months of March and April in all our catch points. These low aggressive densities are thought to be due to the total drying up of the Comoé River at the larval site in Kafolo. This drying up of the river constituted an unfavourable condition for the development of the pre-imaginal stages and consequently of the adults. This finding resulted in a partial or total interruption of the population from this breeding site. These results were similar to those of Koala and his collaborators who did not collect any black flies in March at Badara Karaboro and Badara Dogossè because the Comoé had dried up completely in these locations (Koala *et al.*, 2015). Black flies densities were higher in the rainy season than in the dry season. Indeed, their densities increased from May onwards, with the arrival of the first rains. There was a resumption of the flow and a rise in the level of the river. The rains reached their peak in August and September. The floods led to an increase in the amount of support, which consisted mainly of branches and leaves of the (submerged) vegetation along the riverbed. The large amount of submerged vegetation combined with the rapid flow of the river provides ideal conditions for the establishment of the pre-imaginal stages of the black flies, resulting in an increase in the imaginal population. Indeed, during the second half of the rainy season, i.e., from August to October, the black flies densities were very high, i.e., 3 times the tolerable threshold of 30 bites/person/day (Quillévéré 1979); with a peak in September. These rates reflected the nuisance and probably the risk of onchocerciasis transmission to which the populations are exposed. Koala *et al*. also observed in their study in the upper Comoé River, that black flies aggression was highest in September (Koala *et al.,* 2019). The situation in the deposit near Kafolo is that described by Le Berre (1966) and Philippon (1978) as a variation, of the synchronous type. This type of variation has also been observed by many authors ((Barbazan *et al*. 1998), (Coulibaly F., 2007), (Eisenbarth, 2016), (Yapi Y. G., 2014) and (Koala *et al.,* 2019)) in their study. The activity of an Insect, in whatever form it occurs, is never constant and varies according to the different hours of the day and night (LE Berre, 1966). Regarding black flies aggressiveness, the first observations on the stinging times made by Dry, as early as 1921 (Dry, 1921) and then by Blaclock in 1926 (Blaclock (1926)) made it possible to specify the period of daily aggressiveness, which was from 7 to 18 hours. Hourly variations in their aggression were subsequently the subject of numerous studies (Crosskey, 1955); (Crisp, 1956) and (L. Davies, 1957)). In this study, during the dry season, two periods of intense aggression were observed: the first between 9 and 11 am and the second much more important at the end of the day (between 4 and 6 pm). However, in March and April, this aggressiveness was not constant throughout the day. There were time slots where it was zero. This variation in the daily aggressiveness rate would be due to the variations in temperature and relative humidity during the day. From 11 o'clock onwards, the aggressive density dropped due to the rise in temperature, which resulted in a drop in black flies aggressiveness. At the end of the day, the temperatures became low again, resulting in an increase in black flies aggression. These results were similar to those described by Lewis (1961) and Le Berre (1966). These two authors observed a curve with two peaks in the dry season: the first in the morning, the other in the late afternoon. The rainy season was accompanied by a drop in temperature that predominates most of the time during the day. This atmospheric condition was favourable to black flies activity and was reflected in the importance of black flies aggressiveness, which was not only early (early morning) but was spread over all the time slots of the day. As a result, there was no drop in black flies aggressiveness in the middle of the day as was the case in the dry season. In the last hour of catch (17:00-18:00), the decline in temperature and rise in relative humidity further intensified black flies aggression to a maximum; achieving a single peak in the evening. Crosskey (1955) also noted in his study that in the rainy season, during which the maximum temperature did not exceed 32°C, there was no noticeable decrease in catches in the middle of the day. He described a daily catch curve with a single peak at the end of the day. The aggressiveness of female black flies was closely related to variations in meteorological parameters, including temperature, humidity, air pressure and light (Rubtzov 1936, Harker, 1961). It was observed in this study that, in general, black flies aggressiveness evolved in the opposite direction to temperature throughout the year. It evolved in the same direction as relative humidity during most of the year except during the months of January, February, and December during the harmattan, in dry season. Indeed, it appeared from these observations that the highest rates of aggressiveness in the dry season were recorded during the months of January, February, and December. During these three months, the harmattan wind prevailed. This wind (harmattan) with low monthly average temperatures of 26.64°C and 28.18°C (varying between 16 and 34°C) and low monthly relative humidity of 17.09 and 16.45% (varying between 7 and 29%) favoured relatively high black flies aggressivity. The aggressiveness of the black flies thus evolved in the opposite direction to the relative humidity and in the opposite direction to the temperature. In March-April, with the end of the harmattan, there was a rise in temperatures with very high monthly averages of 31.81° (March) and 35.09° (April) and low monthly averages of 12.73% and 10.09% of relative humidity. These extreme atmospheric conditions led to a drying up of the river at the level of the larval site, the breeding ground of the black flies. The conditions necessary for the development of the black flies did not exist, and the population from the breeding site was completely interrupted. Hence the low black flies densities observed, 4.5 and 1.5 bites/person/day. The aggressiveness of the black flies thus evolved in the same direction as the relative humidity and in the opposite direction to the temperature. During the rainy season, the increase in relative humidity and the decrease in temperature combined with the rise in the water level of the river to create favourable conditions for the development of the preimaginal stages, resulting in an increase in the imaginal population. This suggested that black flies aggressiveness evolved with relative humidity and inversely with ambient temperature throughout the rainy season. Most authors recognised the predominant role of temperature in the daily attack frequency of female black flies (Underhill, 1940); (Davies, 1957a); (Usova and Kulikova, 1958). However, for these authors, hygrometry plays only a secondary role in the aggressiveness of simulids (Le Berre, 1966). For Crisp (1956), humidity influences the stinging rate, but he observed a certain amount of activity when humidity is very low. Other authors even consider that "relative humidity has no influence on the stinging activity of black flies" (Detinova and Beltukova, 1958).

CONCLUSION AND APPLICATION OF RESULTS

This study showed, on the one hand, the importance of the aggressiveness of black flies in Kafolo. Indeed, outside the months of March and April, the number of bites/man/day recorded is generally higher than the tolerable threshold (30); it reached 126 bites/man/day in September. The aggressiveness of the hatchlings is highest in the late afternoon. Furthermore, the study showed that this aggressiveness is influenced by the climate and the environment. It varies with the seasons and with the water levels in the river. The aggressiveness of the fish is not always in the same direction as the relative humidity and is always in the opposite direction to the temperature. These results could help in the development of control measures against black flies bites responsible for skin lesions and allergies, but also and above all responsible for the transmission of human onchocerciasis.

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