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Evaluation of the physicochemical indices of blackflies (Diptera: Simuliidae) breeding sites in Delta State, Nigeria: Implication for onchocerciasis control

Joseph Oghenebukome Onojafe, Andy Ogochukwu Egwunyenga*, Jephtha Christopher Nmor

Department of Animal and Environmental Biology, Delta State University, Abraka, Nigeria

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ABSTRACT

Objective: To determine the ecological parameters affecting the distribution of *Simulium damnosum* immature stages in some rivers within the endemic areas of Delta State, Nigeria.
Methods: *Onchocerca* larvae were observed and identified for each river. An average sized colander with fine mesh was used to scoop the area to obtain the larvae along with other benthos. Physiochemical characteristics of the water at breeding sites were analyzed for a 12 months period. Correlation analysis was performed to establish the association between the larval densities and physicochemical parameters of blackfly.
Results: The seasonal variation in the physical and chemical characteristics of these environments impaired the population dynamics of blackflies. The physicochemical parameters significantly varied among breeding sites ($P < 0.05$), in which the temperature of surface water ranged between 23.2 °C and 30.3 °C, water flow velocity ranged between 0.4 and 1.3 m/s, dissolved oxygen ranged between 5.1 and 9.0 mg/L and pH ranged between 5.4 and 7.4. The mean collection of *Simulium* larvae was the highest in River Otor (44.1) and the least in River Namormai (19.1). There was significant difference ($P < 0.05$) in the number of larvae collected from the sampled rivers. Also, the number of larvae collected significantly correlated with surface water temperature, water flow velocity, dissolved oxygen and pH.
Conclusions: This study identified significant correlations between physicochemical parameters and blackfly larvae densities thus providing a precontrol evidence-based data for the control of onchocerciasis in the endemic areas of North Delta.

1. Introduction

Blackfly (*Simulium* spp.) is a serious public health and socio-economic problems due to transmission of *Onchocerca volvulus* causing human onchocerciasis. The disease is endemic in many parts of the world, especially in Sub-Saharan, Africa.

Blackflies are bloodsucking insects that breeds in fast flowing and well-aerated lotic freshwater bodies with different physiochemical properties, depending on topography, climate, geology and biota[1,2]. Variation in the physical, chemical and biotic compositions of such water may exert effect on the life of aquatic fauna, since the epidemiology of onchocerciasis depends on presence of favorable local ecosystem for successful breeding of the vector[3].

Study conducted by Onojafe *et al*. showed the current prevalence and distribution of human onchocerciasis in endemic communities of Delta State, Nigeria[4]. In Nigeria, particularly Delta State, the human onchocerciasis is commonly managed by the application of ivermectin and onchocerciasis epidemic resulted from the biting by intense blackflies was reduced by implication of ivermectin[5]. Therefore, community targeted onchocerciasis control programs should focus on the vector, parasite and host.

This study was carried out to evaluate the physicochemical factors affecting the distribution and abundance of the larvae of blackflies [*Simulium damnosum* (*S. damnosum*)] in the endemic communities of Delta State, Nigeria. Recognizing the ecological factors influencing the distribution and population dynamics

*Corresponding author: Andy Ogochukwu Egwunyenga, Department of Animal and Environmental Biology, Delta State University, Abraka, Nigeria.
Tel: +2348033907760
E-mail: aoegwunyega@yahoo.com
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of this vector is crucial for the development of effective control program.

2. Materials and methods

2.1. Study area

This study was conducted in three local government areas including Aniocha North, Aniocha South and Oshimili North located in Delta State, Nigeria. The study sites have a tropical climate characterized by dry and rainy seasons with a slight break in August. Also, there are three rivers running through the study area, namely, River Ohe, in Aniocha North local government area, River Namormai, in Aniocha South local government area and River Otor, in Oshimili North local government area. Samples were collected from along the river sides during the period extending from January, 2011 to December, 2011.

2.2. Water sample collection and analysis

All on site determinations and collections of water samples were carried out between 9:00 am and 11:00 am. Water samples for dissolved oxygen (DO) determination were collected using amber bottles. Water samples were analyzed in the laboratory within 24 h following the collection. Temperature of surface water was measured *in situ* using calibrated mercury in glass thermometer. DO was determined on site just after collection of the water sample using DO meter (Cole Palmer, model 5946–75). H^+ concentration (pH) was measured using a pH meter (Metrohm 827 pH lab). Water flow velocity was identified by a weighed ping-pong method as described by Ikomi and Owabor, in which a weighed ping-pong was released at one end and allowed to float over a known distance and then the time taken to cover the distance was recorded[6]. The flow velocity was expressed as distance covered per second.

2.3. Larval prospection

Prior to larval prospection, suitable portions of the rivers for the presence of the blackfly larvae were identified. Thereafter, vegetation, stone or rock surfaces in the lotic areas of the rivers were examined, and movable substrate with Simuliidae larvae were collected and kept in an ice box for onward transportation to the laboratory. In addition, a colander with fine mesh was also used to collect aquatic blackfly larvae along with other benthos. Larvae were then separated from substratum using a forceps and preserved in 80% alcohol for identification using the keys of Crosskey[7,8]. Larvae were sampled from each study site at 10 days intervals from January to December 2011.

2.4. Data analysis

Data were submitted to analysis of variance using Graph Pad Prism version 5.0 and correlation analysis was performed to determine association between physiochemical parameters and number of blackfly larvae. All tests were performed at 5% of probability.

3. Results

3.1. Physicochemical parameters

The physicochemical characteristics of sampled water from different sites were presented in Table 1. Results showed that the temperature of the surface water ranged between 23.2 °C and 30.3 °C, depending on site. On average, the highest water temperature was recorded for River Otor (26.60 °C), followed by River Namormai (26.20 °C) and River Ohe (25.90 °C), respectively, with no significant differences among them ($P > 0.05$). The rivers varied widely in the mean flow velocity. Otor river displayed the utmost flow velocity (0.95 m/s) and DO (7.90 mg/L), while flow velocity and DO were least for Namormai River. There were no significant differences in pH among all study sites.

Figure 1 shows the monthly variation in the surface water temperature in the sampled rivers. For all three rivers, there was slight variation in the monthly water temperature. In general, water temperature was higher in the dry season months (January, February and December) and lower in the wet season months (June to September). There was no significant difference in the monthly water temperature for all three rivers ($P > 0.05$).

The water flow velocity for all three rivers showed significant variation ($P < 0.05$). For all months, the flow velocity was

Table 1

Mean and range of physicochemical parameters of the sampled rivers in the study area.

Parameters		River Ohe in Aniocha North L.G.A	River Namormai in Aniocha South L.G.A	River Otor in Oshimili North L.G.A
Physical	Water temperature (°C)	23.2–29.8 (25.90)	24.2–30.2 (26.20)	24.4–30.3 (26.60)
	Flow velocity (m/s)	0.7–0.9 (0.78)	0.4–0.5 (0.51)	0.7–1.3 (0.95)
Chemical	Dissolved oxygen (mg/L)	6.1–8.6 (7.10)	5.1–7.1 (6.00)	6.5–9.0 (7.90)
	pH (H^+ concentration)	5.4–7.1 (6.50)	5.4–6.4 (6.00)	5.6–7.4 (6.40)

L.G.A: Local government area.

consistently lower for River Namomai and showed the highest for River Ohe with a peak in June and July (Figure 2). A posterior comparison using Duncan multiple range test indicated that Rivers Ohe and Otor were not statistically different ($P > 0.05$) from each other, but were both significantly different ($P < 0.05$) from the means of River Namormai.

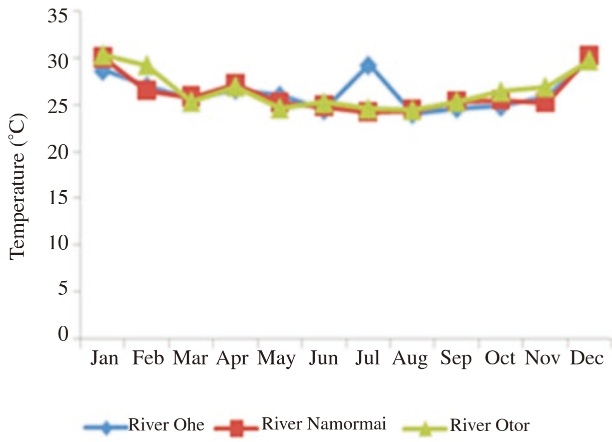

Figure 1. Monthly variation in the surface water temperature of sampled rivers in 2011.

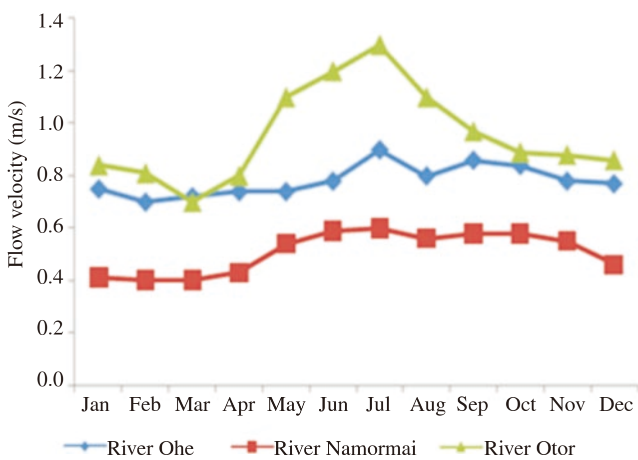

Figure 2. Monthly variation in water flow velocity of sampled rivers in 2011.

The monthly variation of DO in the water bodies sampled was shown in Figure 3. DO content ranged between 5.1 and 9.6 mg/L at the time of sampling. There was similar trend in the pattern of monthly variation in DO among the rivers. The highest values occurred during the wet season months (June to October). DO was significantly different ($P < 0.05$) among the various rivers. There was a wider range of DO variation during the period under study (4.4–7.1 mg/L). Higher values (6.2–7.1 mg/L) were observed during the rainy season. Generally, River Otor had relatively higher values in DO during the period of study (Figure 3).

The monthly pH levels fluctuated slightly in all three rivers (Figure 4). A pH range of 5.6–7.4 was observed during the sample period. Mostly, the pH levels were slightly acidic with a tendency towards neutrality and slight alkalinity during the rainy season. There was however, no clear pattern of seasonal changes in the pH levels among the three rivers, though River Namormai was found to be more acidic during most of the months.

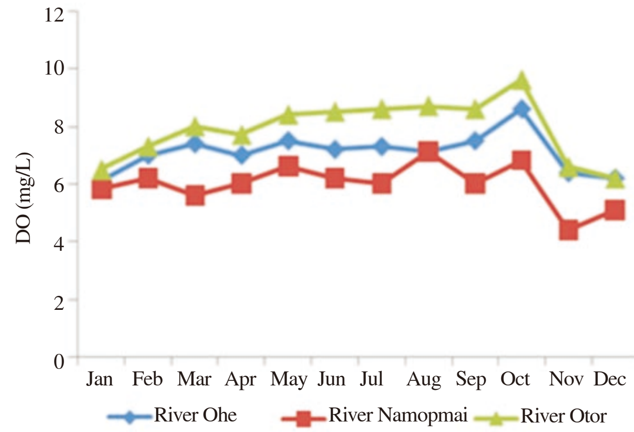

Figure 3. Monthly variation in DO of sampled rivers in 2011.

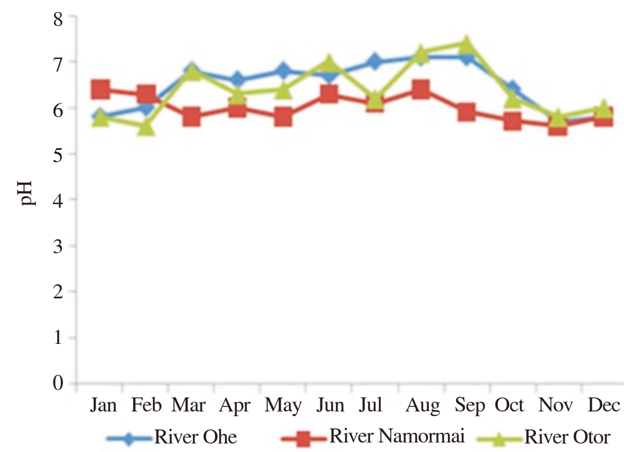

Figure 4. Monthly variation of pH of sampled rivers in 2011.

3.2. Collection of Simulium larvae from the breeding sites

Table 2 shows the monthly collection of *Simulium* larvae from the sample sites in the three rivers. Of the 1 124 larvae collected from the three rivers, 529 larvae were collected from River Otor thus accounting for 44 monthly mean. In River Ohe, 416 larvae were collected, with a monthly mean of 35. While in River Namormai, a total of 179 larvae were collected with a monthly average of 15. There was significant difference in the number of larvae collected from the rivers ($P < 0.05$). Also, Table 2 showed that the highest number of larvae was collected in River Ohe in the month of August (74), while in River Narmomai and River Otor, the highest was collected in September.

3.3. Relationship between number of larvae collected and the physicochemical parameters

Results of the correlation analysis performed to determine the co-relationship between the numbers of blackfly larvae with the physicochemical parameters measured were shown in Table 3. Except for pH, the correlation between blackfly larvae number and physicochemical parameters revealed a consistent trend across the water bodies. For all three water bodies sampled, water temperature showed a negative association with the number of blackfly larvae collected, though the association was stronger in River Otor (r = –0.6499). Flow velocity showed significant positive relationship with larvae density. However, the correlation was stronger in River Namormai (r = 0.8694) and River Ohe (r = 0.8256). Also, there was significant positive relationship with larvae density and DO in all water bodies. The correlation was twofold stronger in River Otor (r = 0.6826) than in River Namormai (r = 0.2270). Furthermore, relationship between pH and blackfly larvae density revealed a different pattern. The association was significantly positively related with blackfly larvae density in River Ohe (r = 0.7179) and River Otor (r = 0.6170) while in River Namormai, it was weakly negatively related (r = –0.1646).

Table 2

Monthly collection of *Simulium* larvae from sampled portions in three rivers.

Months	River Ohe in Aniocha North L.G.A	River Namormai in Aniocha South L.G.A.	River Otor at Aganika camp in Oshimili South L.G.A.	Total
January	10	2	18	30
February	8	0	14	22
March	7	1	11	19
April	17	12	29	58
May	32	16	46	94
June	48	21	59	128
July	66	28	71	165
August	74	19	62	155
September	69	33	96	198
October	51	21	62	134
November	20	16	40	76
December	14	10	21	45
Monthly mean	35	19	44	94
Total	416	179	529	1124

Table 3

Correlation coefficients for number of larvae and physicochemical parameters.

River		Number of larvae	Water temperature	Flow velocity	DO	pH
Ohe	Water temperature	–0.4278				
	Flow velocity	0.8256*	–0.0341			
	DO	0.4963*	–0.5601	0.3678		
	pH	0.7179*	–0.4829	0.4284	0.5978	
Namormai	Water temperature	–0.5859				
	Flow velocity	0.8694*	–0.4465			
	DO	0.2270*	–0.3706	0.1037		
	pH	–0.1649	0.0719	–0.2165	0.4477	
Otor	Water temperature	–0.6499				
	Flow velocity	0.6797*	–0.5918			
	DO	0.6826*	–0.7793	0.4724		
	pH	0.6199*	–0.7203	0.3445	0.6018	

*: $P < 0.05$.

4. Discussion

Onchocerciasis caused by *Onchocerca volvulus*, is considered among the neglected tropical disease and the second leading cause of infectious blindness in the tropical nations[9-11]. There are several reports on the prevalence of onchocerciasis in Delta State, Nigeria[4,12,13].

This study reports for the first time the ecological parameters influencing the abundance and abundance of *Simulium* damnosium in Delta State, southern Nigeria. This study found no significant variation in the surface water temperature in the three water bodies studied. This is expected as the study areas that are contiguous and are characterized by similar climatic factors and vegetation cover. Also, surface water temperature was found to be higher in the dry season months compared to the wet season months. The abundance of *Simulium* larvae in the breeding sites synchronizes with the temporal variation in surface water temperature. The higher abundance in the blackfly larvae in the rainy months is an expected finding, given that the abundance and density of surface dwelling fauna are temperature dependent. That significant higher number of blackfly larvae caught in the rainy season months confirm that *S. damnosum* breeds in the rainy season. Findings of this study agree with the reports of Opara and Fagbemi[2], and Opara *et al*.[14], who separately reported higher density of *S. damnosum* during the rainy seasons.

Results from this study identified significant association between physicochemical parameters and larvae density in the studied water bodies thus suggesting the plausible influence of these parameters to blackfly larvae density. This study showed a negative correlation between water surface temperature and larvae density. This observation suggests that there is a temperature limit for the development of blackfly larvae. Bernotiene and Bartkeviciene observed that higher temperature limits the distribution of larvae density[15].

In this study, significant positive correlation was observed between flow velocity, DO and pH. The positive correlation of blackfly larvae with flow velocity is an expected important finding that is in consonance with other studies[2,16]. Given that feeding is fundamental activity in larvae life and increased flow velocity translates to increased availability of food for filter feeders as well as increased water aeration. This possibly explains the positive association between flow velocity and DO observed in this study, thus confirming flow velocity as an important factor in the breeding of the blackfly. The high density of *S. damnosum* larvae observed in both River Ohe and River Otor could be attributed to the higher mean flow velocity and DO as compared to that of River Namormai. These findings further confirm the significance role of water flow velocity and DO as key factors that influence blackflies abundance in suitable water bodies.

This study found pH to be an important contributory factor in blackfly larvae abundance in the study area. There was a strong positive association between pH and larvae density in both River

Ohe (r = 0.717 9) and River Otor (r = 0.619 9). This finding concurs with previous studies[2]. In this study, the mean annual range of pH was 6.0–6.5 (Table 1). This result is in agreement with the report of Krüger *et al*. that observed a similar annual pH range[17]. It has been reported that *S. damnosum* in tropical rain forest of West Africa breeds mainly in acidic water of pH 5.7-6.2[2].

This study did not consider parameters like ionic composition, conductivity and geology of the riverbeds. It is possible that these parameters may interact with the considered physic-chemical parameters to influence the suitability of the rivers for the breeding of blackfly. Further study will be needed to consider wide array of parameters. Secondly, we sampled for only 12 months, considering the variation in climatic factors, sampling for longer period may reveal a more reliable contributing factors. Given these limitations, caution should be taken in generalizing our findings.

Despite the limitation of this study, this study adds strength to community based onchocerciasis control. This study has identified surface water temperature, flow velocity, pH and DO as the key indices influencing the abundance of *S. damnosum* and its breeding sites are suitable with the study area. Given that onchocerciasis prevalence is expected to be higher in areas with suitable breeding sites and an understanding of the influencing indices may help identify high risk areas for onchocerciasis control programs.

Conflict of interest statement

We declare that we have no conflict of interest.

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