



Ecological characteristics of *Simulium* breeding sites in West Africa



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ABSTRACT

Twenty-nine taxa of *Simulium* were identified amongst 527 collections of larvae and pupae from untreated rivers and streams in Liberia (362 collections in 1967–71 & 1989), Togo (125 in 1979–81), Benin (35 in 1979–81) and Ghana (5 in 1980–81). Presence or absence of associations between different taxa were used to group them into six clusters using Ward agglomerative hierarchical cluster analysis. Environmental data associated with the pre-imaginal habitats were then analysed in relation to the six clusters by one way ANOVA. The results revealed significant effects in determining the clusters of maximum river width (all $P < 0.001$ unless stated otherwise), water temperature, dry bulb air temperature, relative humidity, altitude, type of water (on a range from trickle to large river), water level, slope, current, vegetation, light conditions, discharge, length of breeding area, environs, terrain, river bed type ($P < 0.01$), and the supports to which the insects were attached ($P < 0.01$). When four non-significant contributors (wet bulb temperature, river features, height of waterfall and depth) were excluded and the reduced data-set analysed by principal components analysis (PCA), the first two principal components (PCs) accounted for 87% of the variance, with geographical features dominant in PC1 and hydrological characteristics in PC2. The analyses also revealed the ecological characteristics of each taxon's pre-imaginal habitats, which are discussed with particular reference to members of the *Simulium damnosum* species complex, whose breeding site distributions were further analysed by canonical correspondence analysis (CCA), a method also applied to the data on non-vector species.

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1. Introduction

Blackflies of the genus *Simulium*, which includes vectors of onchocerciasis such as the *S. damnosum* complex, lay eggs in flowing water where their larvae and pupae develop before eclosion. As different species are found in differing categories of streams and rivers, egg-laying females presumably respond to cues in their habitats when selecting oviposition sites together with factors such as oviposition pheromones released by females that have already laid eggs in a particular micro-habitat (McCall, 1995; McCall et al., 1997). For the *S. damnosum* complex, the environmental cues include river size, river discharge rate, pH, conductivity and temperature (Quillévére et al., 1976, 1977; Cheke, 2012), but to date no multivariate analyses of breeding site environmental variables for this important group of onchocerciasis vectors have been con-

ducted, although some Central American vectors have been studied using canonical correspondence analysis (CCA) (Millest et al., 1999). Similar studies in the tropics involving both principal components analysis (PCA) and CCA have been conducted on the blackfly faunas of Thailand (Srisuka et al., 2015) and Malaysia (Ya'cob et al., 2016a, 2016b), with related studies using presence-absence data published for Brazil (Couceiro et al., 2014) and Algeria (Chaoui Boudghane-Bendiouis et al., 2014). CCA has also been applied to environmental variables in relation to *Simulium* breeding in Europe, especially to blackfly data from the Carpathian Mountains (Illéšová et al., 2008, 2010; Strangler et al., 2013). Such studies have revealed the significance for determining blackfly breeding habitats of variables such as altitude, water temperature, current speed, discharge, slope, river width and depth, pH, conductivity, oxygen saturation and vegetation. The purpose of this retrospective study was to examine whether data on some but not all of the above variables together with some others could be used to characterise where immature stages of different species of West African Simuliidae might occur. Particular attention was paid to the various vectors of onchocerciasis found.

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We present analyses of data collected in Benin, Ghana, Liberia and Togo, consisting of information on the presence or absence of larvae and/or pupae of *Simulium* spp. in riverine breeding sites in relation to environmental characteristics of the sites surveyed in order to establish trends and relationships between the species' occurrences and the environmental variables. Regarding the vectors of onchocerciasis amongst the species identified, it is hoped that the results will help to identify the habitat types in which they may be found breeding and, in some cases, indicate the species likely to be present in a particular river. In addition, they may assist in predicting likely changes in geographical distributions in relation to climate change.

2. Methods

During field work in Liberia in the 1967–1971 period, all rivulets, streams and rivers in which *Simulium* spp. could breed were examined by R. Garms for the presence of larvae and pupae and, in many cases, traps were placed to collect Crustacea which might harbour pre-imaginal stages of phoretic species of blackflies, as described by Garms (1974). In Benin, Ghana and Togo only river-

ine sites that might harbour breeding *S. damnosum* s.l. were prospected by either or both of R. A. Cheke and R. Garms as part of research programmes and routine activities organised by the WHO Onchocerciasis Control Programme (OCP), but restricted to the period 1979–81 in rivers yet to be treated with insecticides. Most of these sites were accessed by helicopter and environmental data were collected simultaneously when pre-imaginal stages of *Simulium* were searched for. The collections were standardised insofar as a checklist was used for recording information; in Liberia all possible sites and substrates where immature stages of any species of *Simulium* might be found were searched but in Benin, Ghana and Togo searches were concentrated at positions likely to harbour members of the *S. damnosum* complex. The environmental data included measurements and subjective assessments of habitat characteristics (Table 1). Regrettably, no data on pH, dissolved oxygen concentrations or conductivity were obtained in sufficient amounts to be included in the analyses. For the multivariate analyses described below, missing values for environmental variables were replaced by their overall mean values.

Data were collated from 527 sites in Liberia (362 collections in 1967–71 & 1989), Togo (125 in 1979–81), Benin (35 in 1979–81)

Table 1
Details of measurements made at *Simulium* spp. breeding sites and of subjective assessments of habitat characteristics.

Measurements						Notes
River width	Unit					
	m					
River depth	cm					
River discharge	m ³ s ⁻¹					Sometimes estimated without measurements
River water temperature	°C					
Air temperature (wet bulb)	°C					
Air temperature (dry bulb)	°C					
RH	%					Calculated from wet and dry bulb temperatures
Height of waterfall	m					
Length of <i>Simulium</i> breeding area	m					
Altitude	m a.s.l.					
<i>Subjective habitat assessments</i> (1–5 scales; 1–3 scales for light conditions and terrain)						If >1 class recorded, then highest used
	1	2	3	4	5	
Type of water	Trickle	Streamlet or stream	Small river	Medium river	Large river	
River water level	Trickle	Low	Medium	High	Inundating	
River bed	Rocky (stones > 10 cm across)	Stony (mostly stones < 10 cm across)	Earthen	Sandy	Muddy	
River features	Sandy island	Fish fence	Bridge	Rapids	Rocky barrier	
Slope	Inconspicuous	Moderate	Considerable	Terraced	Waterfall	
Current	Smooth	Slow	Swift	Fast	Very fast	
Vegetation	None	Plants on banks, on rocks or overgrowth on rocks	Trailing grasses or plants	Bushes	Trees	
Light conditions	Open to sun	Partially shaded	Shadowed			
Environs	Grassland	Farmland or plantation	Low bush or savanna	Forest	High forest	If >1 class recorded, then highest used unless category 2 involved, then category (2) used to highlight effects of man
Terrain	Plain	Hilly	Mountainous			
Supports	Stones or rocks	Dead leaves	Sticks or roots	Trailing grasses or plants	Bushes	

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