Effect of Temephos 20EC on Non-Target Saxicolous Fauna of a Tropical African Island River at First Treatment

Joseph S. Amakye
CSIR-Water Research Institute, P O Box AH 38, Achimota, Ghana
E-mail: wri@ghana.com

Abstract

River Musola on Bioko Island in the Republic of Equatorial Guinea was treated with temephos 20EC, a *Simulium* larvicide, in March 1999 under a pilot experiment to eradicate *Simulium damnosum* s.l. from that island. The mean density of the saxicolous macroinvertebrates prior to temephos treatment of the river was 5,946.7±2,065.7 individuals m^{-2}. The density of macroinvertebrates observed 24 h after treatment with temephos was 4,062.2±2,588.0 individuals m^{-2}, indicating 31.7% reduction in the density of the population. There was 100% reduction in density of Odonata, Hydroptilidae, Ecnomidae, Leptoceridae and Tanypodinae in the post treatment samples. Baetidae and Orthocladiinae were affected significantly by temephos ($P \leq 0.1$). Whereas impact of temephos on *Cheumatopsyche digitata* (Trichoptera: Hydropsychidae) was marginal (-16.7%), there was complete loss of *C. falcifera* (100%) from the river, following treatment with the larvicide, indicating differential response to the larvicide by these sympatric species. In general, 'Filtering Collectors' (73%) dominated the saxicolous biocoenosis prior to treatment with temephos. However, no 'Grazers' or 'Scrapers' were present in the saxicolous community of the section of the river studied during the pre-treatment period. The 100% reduction in density observed for many taxa in the biocoenosis, in the immediate post treatment period was attributed to the low discharge of the river and the low population densities of the various taxa observed at the time of the experiment, as well as the extremely heterogeneous nature of the river bottom. It is proposed that the gallery forests be maintained to aid conservation of the faunistic diversity of the river.

Introduction

Onchocerciasis is a filarial worm infestation that eventually leads to blindness in many rural communities in Africa, the Middle East and Central America. The presence of the disease has led to desertion of fertile agricultural lands in river valleys, incapacitated productive segments of rural populations and plunged many communities below the poverty line (WHO, 1985). The World Health Organisation (WHO) started a vector control programme in West Africa in 1974 to break the cycle of transmission of the disease. Under the programme, temephos was applied to the breeding sites of the vector fly, *Simulium damnosum*, at weekly intervals, and this reduced the incidence of new infections of onchocerciasis in West Africa by 99% (WHO, 1994). Thus, the risk of infection is currently low in areas where onchocerciasis is under control (Anon., 1999).

Following from the success of the Onchocerciasis Control Programme (OCP) in West Africa, WHO commenced control programmes in other African countries where onchocerciasis is endemic. One of the countries targeted by WHO under the African Programme for Onchocerciasis Control (APOC) was the Republic of Equatorial Guinea. The APOC aims at eradicating onchocerciasis from Bioko Island through the elimination of the vector fly, *S. damnosum*. While temephos, the choice chemical larvicide used in the control of *S. damnosum* on Bioko Island, is known to be the least lethal larvicide to non-target macroinvertebrates under the OCP, it is also effective against the larvae of the vector and has good carry downstream of treatment points (Kurtak *et al.,* 1987; APOC, 1998).

Bioko Island is a World Heritage Conservation site, as well as a high species endemic area (Jones, 1994). It was, thus, considered important that the overall impact of temephos on the non-target macroinvertebrates be investigated before operational treatments of rivers on the island began in order to safeguard the aquatic biodiversity of the island. The results of an experimental treatment to control *Simulium* on River Musola, using temephos, are presented in this paper.

Materials and methods

Bioko Island (Equatorial Guinea), lying off the coast of the Republic of Cameroon, is part of an archipelago, of volcanic origin, straddling the Atlantic Ocean between Africa and South America. River Musola takes its source from the Caldera de Luba, at an altitude of 1,500 m above sea level on Bioko Island, flows in a westerly direction and empties into the Atlantic Ocean north of Luba (Fig. 1). A stretch of the river, south of Musola village (3° 26' 3" N, 8° 37' 5" E), was selected for the study. The river at this point was a third order river (Strahler, 1971) flowing through a cocoa plantation with a gallery forest fringing both banks (Fig. 2). The elevation at this point was 500 m above sea level, and the discharge of the river was 0.14 m^3 sec^{-1}. The water was cool (temperature = 23 °C), clear (turbidity = 0.64 NTU), neutral (*p*H = 6.85), low in conductivity (electrical conductivity = 147 µS) and with little particulate matter in suspension (Suspended solids = 8.0 mg l^{-1}). The Habitat Assessment Score was 85 (Barbour & Stribling, 1991).

The standard method for biological assessment of the impact of larvicides on non-target fauna under the OCP was used in this study (Yameogo *et al.*, 1993). A set of five samples was taken from a rocky bottom within a riffle, using a modified Surber sampler 24 h before treatment of the river with temephos 20EC. The effective sampling area of the Surber sampler was 0.0225 m^2. The stretch of the river that was subjected to treatment was also a breeding site for *S. damnosum* s. l. (Fig. 2). A mixture of 100 ml of temephos 20EC made up with water to 10 l was applied to the river over a 2-min period, at a point 200 m above the study area. Under the prevailing hydrological conditions, temephos dosage was expected to be between 0.05 and 0.1 mg l^{-1} during a 10-min passage time over the experimental area. A parallel set of samples was again collected 24 h after treatment with temephos from the same site.

Samples were preserved in the field in 4% formalin and brought to the laboratory for further processing. Samples were examined under a dissecting microscope, all macroinvertebrates sorted out into their taxonomic groups and the individuals identified with the aid of keys (Dejoux *et al.*, 1982). All individuals belonging to a taxon were counted and the mean number estimated. The mean numbers of the various taxa present at the site before and after treatment were compared and the difference in density expressed as a percentage change. Mean numbers of the taxa collected before and after treatment with temephos were subjected to Student's t-test to assess which of the taxa were impacted significantly by

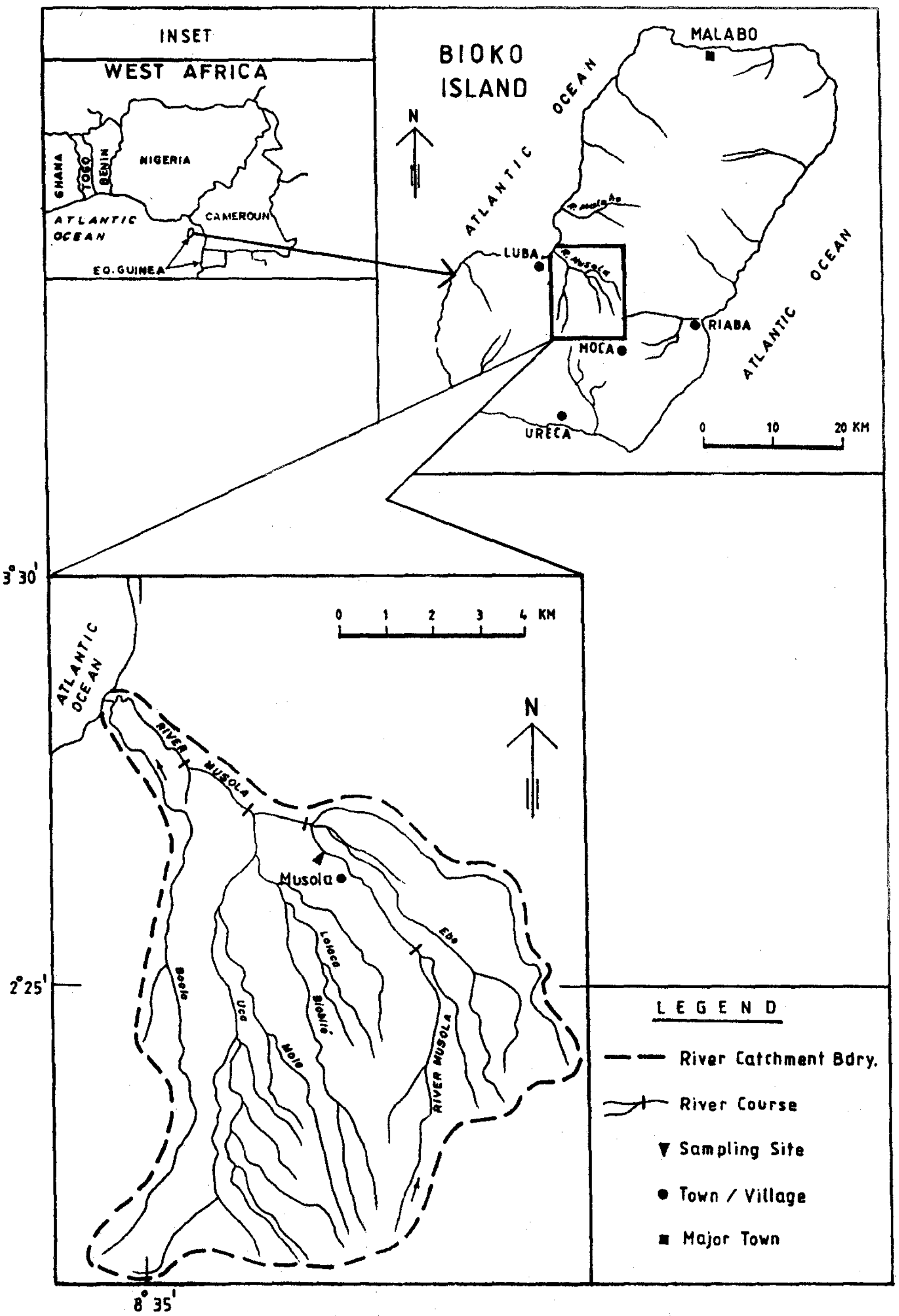

Fig. 1. Map showing location of experiment on River Musola

Fig. 2. River Musola at the time of the study (Note riffles, exposed rocks and boulders).

temephos ($P \leq 0.1$). In addition, proportions of the various 'Functional Feeding Groups' (Merritt & Cummins, 1996) present in the biocoenosis before and after treatment were monitored. Macroinvertebrates from the biocoenosis were assigned to the following 'Functional Feeding Groups' as outlined by Merritt & Cummins (1996):

Functional Feeding Groups	*Taxon*
1. Shredders	Ephydridae
2. Filtering Collectors	Hydropsychidae, Ecnomidae, Ostracoda.
3. Gathering Collectors	Chironominae Baetidae, Tipulidae, Elmidae, Orthocladiinae.
4. Scrapers	Afronurus, Notonurus (Heptagenidae), Eubriidae.
5. Predators	Tanypodinae, Odonata, Hydracarina, some Baetidae (Afrobaetodes, Centroptiloides), some Leptoceridae, some Hydroptilidae

The proportions of the various 'Functional Feeding Groups' present in the biocoenosis before and after treatment with temephos were illustrated as pie charts.

Results

Mean density of saxicolous macroinvertebrates of River Musola was estimated to be 5,946.7 ± 2,065.7 individuals m^{-2} prior to treatment with temephos, and 4,062.2 ± 2,588.0 individuals m^{-2} 24 h after treatment with temephos. The percentages of the constituent macroinvertebrate orders present in the saxicolous fauna before and after treatment with temephos are presented in Fig. 3a and 3b, respectively. The pattern of dominance during the pre-treatment period was Trichoptera (72.7%) > Diptera (16.8%) > Ephemeroptera (7.4%) > Odonata (1.7%) > Coleoptera (1.5%). The pattern in the post treatment period was Trichoptera (86.0%) > Diptera (11.4) > Coleoptera (2.2%) > Ephemeroptera

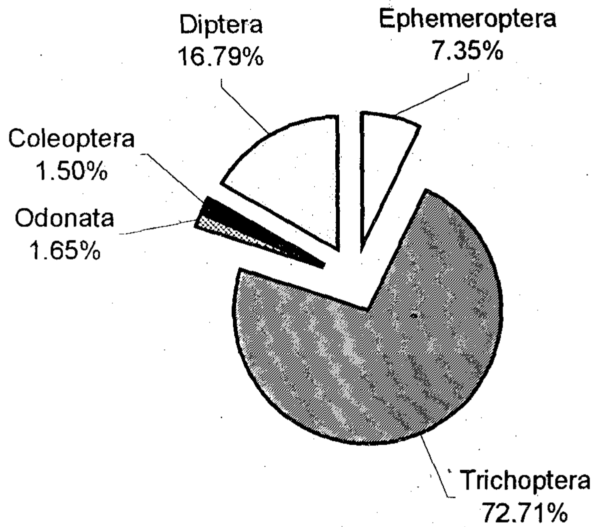

Fig. 3a. Composition of saxicolous fauna of River Musola prior to treatment with temephos

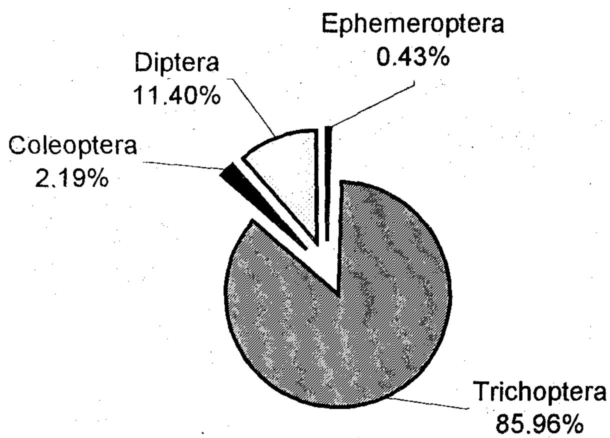

Fig. 3b. Composition of saxicolous fauna of River Musola 24 h after treatment with temephos

(0.4%). Odonata was absent in the post treatment period.

The densities of families of various aquatic insects collected in the pre-treatment samples are presented in Fig. 4a. Fourteen families were present during this period with the pattern of their densities in order of their abundance, being Hydropsychidae (4,266.66 m^{-2}) > Chironominae (648.89 m^{-2}) > Baetidae (435.56 m^{-2}) > Orthocladiinae (195.56 m^{-2}) > Elmidae (88.89 m^{-2}) > Libellulidae (80.0 m^{-2}) >Tanypodinae = Ephydridae (26.67 m^{-2}) > Leptoceridae = Ecnomidae = Calopterygidae = Simuliidae (17.78 m^{-2}) > Hydroptilidae (8.89 m^{-2}). The densities of the various aquatic insects collected in the post treatment period are presented in Fig. 4b. Only seven families were present during the post treatment period. The pattern of their densities was: Hydropsychidae (3484 m^{-2}) > Chironominae (293.33 m^{-2}) >Elmidae (97.78 m^{-2}) > Orthocladiinae (53.55 m^{-2}) > Ephydridae (44.44 m^{-2}) > Baetidae = Tipulidae (17.78 m^{-2}) > Leptoceridae = Hydroptilidae = Ecnomidae = Calopterygidae = Libellulidae = Tanypodinae = Simuliidae (0 m^{-2}). Temephos, therefore, caused a 100% detachment of Leptoceridae, Hydroptilidae, Ecnomidae, Calopterygidae, Libellulidae, Tanypodinae and Simuliidae from the bottom of the river.

The proportions of the various 'Functional Feeding Groups' in the saxicolous macroinvertebrate community of River Musola before and after treatment with temephos are shown in Fig. 5a and 5b, respectively. 'Filtering Collectors', made up mainly of Hydropsychidae, Ecnomidae and Ostracoda, dominated the community. They constituted 72.5 % of the biocoenosis during the pre-treatment period. The 'Gathering

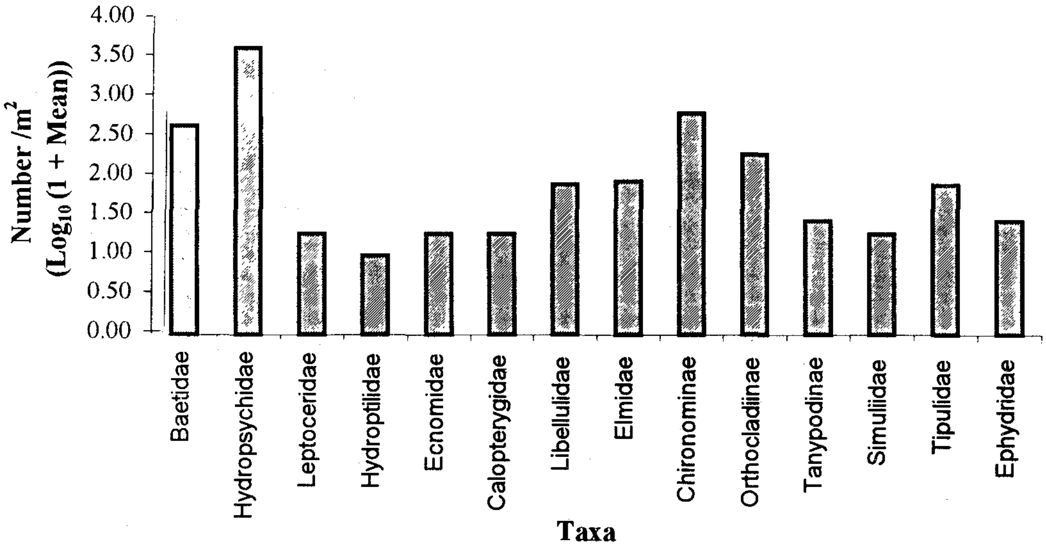

Fig. 4a. Density of commonly occurring aquatic insects in saxicolous fauna of River Musola prior to treatment with temephos

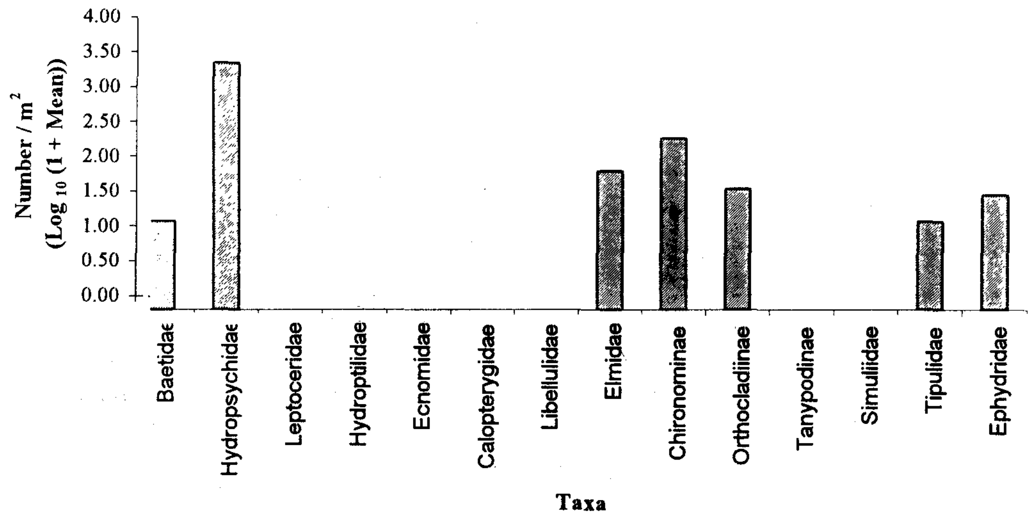

Fig. 4b. Density of commonly occurring aquatic insects in saxicolous fauna of River Musola 24 h after treatment with temephos

Collectors', comprising Chironominae, Baetidae, Elmidae, Tipulidae and Orthocladiinae, constituted 24.4% of the saxicolous macroinvertebrates. The 'Predators' made of Hydracarina, Hydroptilidae, Leptoceridae, Odonata and Tanypodinae, constituted 2.7% of the community. The 'Shredders', consisting of mainly Ephydridae, were scarce (0.4%). The community, however, lacked 'Grazers' and 'Scrapers'. 'Collectors', therefore, constituted about 96% of the macro-

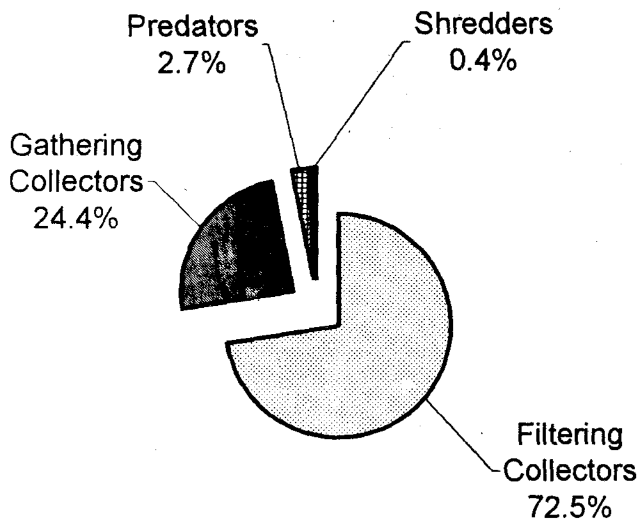

Fig. 5a. Functional Feeding Groups in River Musola prior to treatment with temephos

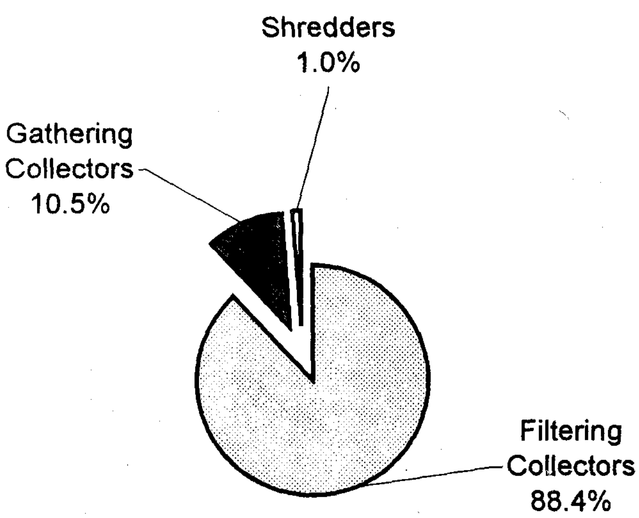

Fig. 5b. Functional feeding groups in River Musola 24 h after treatment with temephos

invertebrates of the pre-treatment, saxicolous community. When pre-treatment and post treatment periods were compared, a marked reduction in the percentages of Gathering Collectors' and 'Predators' was observed. Temephos, therefore, impacted more on 'Gathering Collectors' and 'Predators' than on 'Filtering Collectors' in the section of the Musola that was studied.

The effect of temephos on the saxicolous macroinvertebrates of River Musola is also presented in Table 1. The density of the pre-treatment saxicolous community was reduced by 31.7% 24 h after treatment with temephos. The impact of temephos, on the members of the community, however, varied. Twenty-one out of 29 (72%) constituent taxa that were present in River Musola prior to treatment were not found in the post treatment samples. When the mean number of taxa in the pre- and post treatment periods were considered, however, it was observed that temephos caused a 53.5% reduction in the number of taxa soon after treatment with the larvicide. The impact of temephos on Baetidae and Orthocladiinae was significant ($|t| = 2.897$ and 2.579, respectively, $\alpha = 0.05$).

Discussion

The density of saxicolous macro-invertebrates in River Musola (5,946.7 m^{-2}) prior to treatment was lower than those of similar forest zone rivers: Asukawkaw in Ghana (14,373 m^{-2}) (Amakye & Samman, 1981), Marahoué in Côte d'Ivoire (12,134.34 m^{-2}) (ORSTOM, 1977) and

TABLE 1

Effect of temephos 20EC on densities of saxicolous fauna of River Musola

Taxon	*Mean number /Surber sampler*		*% Change*	*t- Statistic*
	Pre-treatment	*Post treatment*		
MICROCRUSTACEA				
Ostracoda	0.20	0.00	-100	1.000
HYDRACARINA	0.20	0.00	-100	1.000
EPHEMEROPTERA	9.80	0.80	-95.92	2.879**
Baetidae	**9.80**	**0.80**	**-95.92**	**2.879****
Centroptilum sp. 1	0.20	0.40	+100	-1.000
Centroptilum sp. 2	7.20	0.40	-94.44	2.510*
Centroptilum sp. 3	2.40	0.00	-100	2.138*
TRICHOPTERA	97.20	84.40	-13.17	0.707
Ecnomidae	**0.40**	**0.00**	**-100**	**1.000**
Ecnomus sp.	0.40	0.00	-100	1.000
Hydropsychidae	**96.00**	**84.40**	**-12.08**	**0.648**
Cheumatopsyche digitata	94.20	84.40	10.40	0.558
C. falcifera	1.80	0.00	-100	1.616
Leptoceridae	**0.40**	**0.00**	**-100**	**1.633**
Oecetis sp.	0.20	0.00	-100	1.000
Hydroptilidae	**0.20**	**0.00**	**-100**	**1.000**
Hydroptilid T24	0.20	0.00	-100	1.000
ODONATA	2.20	0.00	-100	1.833
Zygoptera	0.40	0.00	-100	1.000
Calopterygidae	**0.40**	**0.00**	**-100**	**1.000**
Phaon sp.	0.40	0.00	-100	1.000
Anisoptera	1.80	0.00	-100	1.616
Libellulid O38	1.40	0.00	-100	1.616
Libellulid O49	0.40	0.00	-100	0.374

Table 1 continued

COLEOPTERA	2.00	2.20	+10	-1.000
Elmidae	2.00	2.20	+10	-1.000
Elmidae C6	0.60	1.20	+100	-0.688
Elmidae C90	1.00	0.00	-100	1.291
Elmidae C59	0.40	1.20	+200	-1.633
DIPTERA	22.40	10.40	-53.57	1.617
Chironomidae	**19.6**	**7.80**	**-60.20**	**1.809**
Chironominae	14.60	6.60	-54.9	1.449
Chironomini sp. 1	11.8	6.60	-44.07	1.413
Chironomini sp. 2	0.20	0.00	-100	1.000
Chironomini sp. 3	0.20	0.00	-100	1.000
Chironomini sp. 4	1.40	1.20	-14.29	0.272
Tanytarsini	0.60	0.00	-100	1.500
Orthocladiinae	4.40	1.20	-72.73	2.579*
Orthocladiinae sp. 1	0.80	0.00	-100	1.372
Orthocladiinae sp. 2	1.80	0.00	-100	3.087**
Orthocladiinae sp. 3	0.40	0.00	-100	1.633
Orthocladiinae sp. 4	1.40	1.20	-14.29	0.272
Tanypodinae	0.60	0.00	-100	1.500
Tanypodinae sp.	0.60	0.00	-100	1.500
Simuliidae	**0.40**	**0.00**	**-100**	**1.633**
Simulium damnosum s. l.	0.40	0.00	-100	1.633
Tipulidae	**1.80**	**0.40**	**-77.78**	**0.722**
Ephydridae	**0.60**	**1.00**	**+66.67**	**-0.535**
Other Unidentified Diptera	0.00	1.20	+100	-1.00
Total Number of Individuals	**133.8**	**91.40**	**-31.75**	**2.023***
Number of Taxa	**11.6**	**5.4**	**-53.45**	**2.735****

* $\alpha \leq 0.10$ ** $\alpha \leq 0.05$

Férédougouba (14,000 m^{-2}), a tributary of River Sassandra, in Côte d'Ivoire (Troubat & Lardeux, 1982). Density and diversity of saxicolous macroinvertebrates in West African rivers are enhanced in sections where rheophytes, like *Tristicha trifaria* occur (Dejoux *et al.*, 1981). The protocol for surveillance of the impact of larvicides on non-target fauna of the aquatic environment in the OCP, therefore, recommended that samples of saxicolous fauna should be collected from sections of candidate rivers that have *T. trifaria* growth (Dejoux *et al.*, 1981). In the present study, however, samples were collected towards the end of the dry season when the river was at its lowest discharge and much of the bedrock was exposed. *T. trifaria* had withered in most places and the constituent macroinvertebrates of the biocoenosis, therefore, were at their lowest density. The river also flowed through a cocoa plantation where large amounts of insecticides and fungicides are applied to cocoa trees as part of the regular agronomic practices in the cocoa industry. These agro-chemicals may get washed from the plantation into River Musola and, therefore, may account for the low density of saxicolous macroinvertebrates observed.

The precision of the estimated densities of the saxicolous macroinvertebrates in River Musola was low. The density was 5,946.7 ± 2,065.7 during the pre-treatment period whereas it was 4,062.2 ± 2,588.0 in the immediate post treatment period. Factors that affect the level of precision of estimates of population densities of stream benthos include the patterns of distribution of the benthos in the bottom as well as the sample size (Elliott, 1971; Hellawell, 1978). Most stream benthos, however, have a contagious distribution (Elliott, 1971; Elouard & Jestin, 1982). In such cases, a large sample size would be necessary to ensure greater precision of the estimated population density. In regard of River Musola, a sample size of $n \approx 31$ (replicates) must be collected in order that the estimate fell within 90% of the true population density with 95% probability (Hellawell, 1978). Processing of benthic samples, however, is laborious and time-consuming (Hauer & Resh, 1996). The OCP, therefore, settled on a sample size of five Surber samples, under its protocol for monitoring, with a lower degree of precision of the estimated densities so that duration of sample processing would be short and also allow monthly comparison of results from rivers across the programme area (WHO, 2002). In the case of River Musola, five replicate Surber samples estimated population of the biocoenosis with approximately 30% margin of error of the true density of the community, with 95% probability of occurrence, which is acceptable.

The overall impact of temephos on the non-target saxicolous fauna in River Musola was similar to what was observed in Côte d'Ivoire and Ghana when temephos was applied to rivers in both countries for the first time (Elouard & Troubat, 1979; Amakye, 1980; Dejoux, 1983). The presence of temephos led to increased detachments of macroinvertebrates from bottoms of rivers Marahoué, Sassandra and Bagoé in Côte d'Ivoire as well as River Oti, in Ghana. In the present study, temephos caused 32% loss of macroinvertebrates from the bottom of River Musola. The observed impact of temephos on the non-target fauna was higher in River Musola (32%) than in River Marahoué in Côte d'Ivoire where 24% detachment was observed (Dejoux & Elouard, 1977). The impact of temephos on the macroinvertebrates in River Musola, therefore, fell within the 30 – 50% reduction in population generally observed in rivers in Côte d'Ivoire (Dejoux, 1983).

A back-calculation of the effective concentration of temephos applied to River Musola indicated a concentration of 0.2 mgl^{-1}. This concentration is about twice the desired concentration of temephos for the control of *Simulium damnosum* s. l. during low water periods. The impact of temephos in River Musola, however, was less severe than that observed in River Bagoé where 75% detachment was observed in an overdose experiment (Dejoux, 1983). In the latter instance, it was noted that the concentration of temephos was 10 times the operational concentration used under the OCP. Accidental over-treatments can, therefore, occur in such large-scale campaigns. Also, over-dosage can occur when the breeding site is close to the point of insecticide release, as was the case in this study (Amakye, 1980; Dejoux, 1983). However, even where massive loss of saxicolous macroinvertebrates occurs during initial treatments of rivers with temephos, subsequent larvicidal treatments intended to control *Simulium* elicit smaller losses of the saxicolous fauna (Dejoux, 1983).

In the smaller rivers, at altitudes below 500 m, discharges are too low to support *Simulium* whereas water temperatures above 1000 m are so low (< 20 °C) and lack food so that *Simulium* larvae cannot establish themselves (Ocran *et al.*, 1982; APOC, 1998). Sections of rivers outside the 500–1000 m range on Bioko Island, therefore, would not be treated routinely with temephos (APOC, 1998). The untreated portions of River Musola, therefore, will serve as refugia for the fauna whence they can repopulate the treated sections when the programme for the eradication of the vector ends. Thus, the fauna of River Musola is not in danger of extermination even when accidental over-treatments occur.

As was observed in Côte d'Ivoire, temephos impacted on the Baetidae and Orthocladiinae of River Musola significantly ($P \leq 0.1$). Both taxa are 'Gathering Collectors'. The efficacy of temephos is enhanced in turbid waters (Kurtak *et al.* 1987); temephos tends to adsorb onto colloidal materials, sand and other particulate matter such as detritus (Tomlin, 1997; Kurtak *et al.*, 1987). Thus, the impact of temephos would be greater on 'Gathering Collectors' like the Baetidae and Orthocladiinae than on other 'Functional Feeding Groups' such as the 'Predators' or "Filtering Collectors" as this study showed.

The absence of 'Scrapers' and, to some extent, 'Grazers' in the saxicolous community can be attributed to the gallery forest that shaded the river. The saxicolous macroinvertebrate community, therefore, depended on allochthonous matter supplied by the gallery forest as their food. The dominance of 'Collectors' in the biocoenosis confirmed the dependence of the community on food from the riparian zone.

Environmental degradation like deforestation can lead to changes in the proportions of the 'Functional Feeding Groups' present in a section of a river (Merritt & Cummins, 1996). The changes may eventually alter the competitive advantages of the constituent taxa of the saxicolous community, which may lead to loss of the disadvantaged taxa from the sections of the rivers so impacted (Elouard & Jestin, 1982). It is important, therefore, that the forest cover, especially the gallery forest on the island, is maintained to help in conservation of the faunistic diversity of the rivers on the island and to reduce the added impact that deforestation can have on the non-target fauna during implementation of the programme for the eradication of *Simulium* from the island.

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