Jber. Biol. Stn Lunz 15: 61 - 66 (1995)

THE FLUCTUATIONS OF EPHEMEROPTERA DENSITIES AND SPECIES RICHNESS ON PHYSICALLY-DISTURBED SUBSITES IN A KENYAN RIVER

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ABSTRACT

Physical disturbance experiments on the sediment surface of a tropical river in Kenya were undertaken from June 1993 to January 1994. Spatio-temporal experimental approaches based on continuous disturbance (DUR) and extreme short-term (ESTD), medium short-term (MSTD) and long-term (LTD) disturbances were used on randomly selected subsites. *Afronurus* sp. and *Choroterpes* (*Eu.*) sp. were the most dominant taxa representing 49.4% and 25.6%, respectively, of the total mayfly taxa collected in the MSTD experiments. Physical disturbance had an initial depressant effect on mayfly densities with maximum density recovery after 19d of post-disturbance. Disturbance stabilized species richness in the ESTD experiments. Near-complete defaunation took place within the 14 minutes of continuous disturbance. All the control densities and species richness showed trends which contrasted the disturbed subsites which showed sharp decreases in densities but stabilized species richness.

Key words: Disturbance, Ephemeroptera, river, sediment surface, Kenya

INTRODUCTION

The dichotomy of cause and effect on stream ecosystems has been frequently used to define the disturbance concept. It is a relativistic concept which changes with the scale of observation (Rykiel, 1985) and is poorly studied in the tropics. It may affect a continuum stretching from individual to ecosystem and landscape, and the consequences and mechanisms of disturbance are different at each hierarchical level (Rykiel, op. cit.). Disturbance has been recognised as one of the factors influencing community structure in streams (Flecker & Feifarek, 1994). Mayflies are normally sensitive to disturbance and have frequently been used in water quality studies (e.g. Fremling & Johnson, 1990). However, their response to physical disturbance in Kenya is not known. In the current study, physical disturbance involved overturning, stirring and local shifting of substrates within randomly selected subsites on the streambed. The overall objective of this report was to examine in general the influence of physical disturbance on the density and species richness of the Ephemeroptera community in the Naro Moru River in central Kenya.

MATERIALS AND METHODS

THE NARO MORU RIVER AND THE STUDY SITE

The Naro Moru River (Lat. 0° 03'S, 0° 11'S; Long. 36° 55'E, 37° 19'E) (Fig. 1A) is a 2nd-order river, with the North and South Naro Moru Rivers as its main tributaries. It flows from the western side of Mt. Kenya, and rivulets from Teleki Tarn (4270m a.s.l.), Tyndall Tarn (4475m), Hut Tarn (4488m) and from the remnants of the Darwin and Lewis Glaciers supply its tributaries with water throughout the year. The Naro Moru River discharges into the Ewaso Ngiro, which subsequently discharges into the Lorian Swamp. In its long profile, the river is characterized by riffle-pool sequences. This study was conducted on a 82m-long riffle (0° 10'S, 37° 01'E; alt. 2035m a.s.l.). From the source up to the study site, the altitude drops by 2552m. Riparian vegetation consists of tropical rainforest species and forms a closed canopy (~87% cover) over the study site.

SAMPLING PROCEDURES AND EXPERIMENTAL MANIPULATIONS

Subsites were permanently set randomly on the stream bed of the study riffle (Fig. 1B). Samples were always collected from the upper 10cm of the sediment surface with a modified Hess sampler (area: 3.142dm^2, 80µm mesh-size). Experimental approaches involved disturbance duration (DUR), extreme short-term (ESTD), medium short-term (MSTD) and long-term (LTD) disturbances. Physical disturbances in all these experiments involved local displacement, shifting and stirring of the substrates within the sampled area for three minutes except in DUR experiments where samples were taken every one minute for 14 minutes. The samples were preserved in 5% formaldehyde solution and later sieved through 250µm and 80µm mesh-size nets to separate the debris and larger animals from the smaller ones. The ephemeropterans retained in both sieves were sorted, identified and enumerated. For the MSTD experiments, three subsites (MSTD1, MSTD2 & MSTD3) were set on Transect A on the study riffle and their locations marked with iron stakes in such a manner that the sampler fitted tightly between them. During each sampling occasion, physical disturbance was induced at 1200, 1300, 1500, 1900, 0100, 0900 and 1900 hours. On each collection time, three samples were also taken randomly from the undisturbed control area which was subdivided into ten 1.5 x 3.0 m strata to allow for randomly stratified sampling.

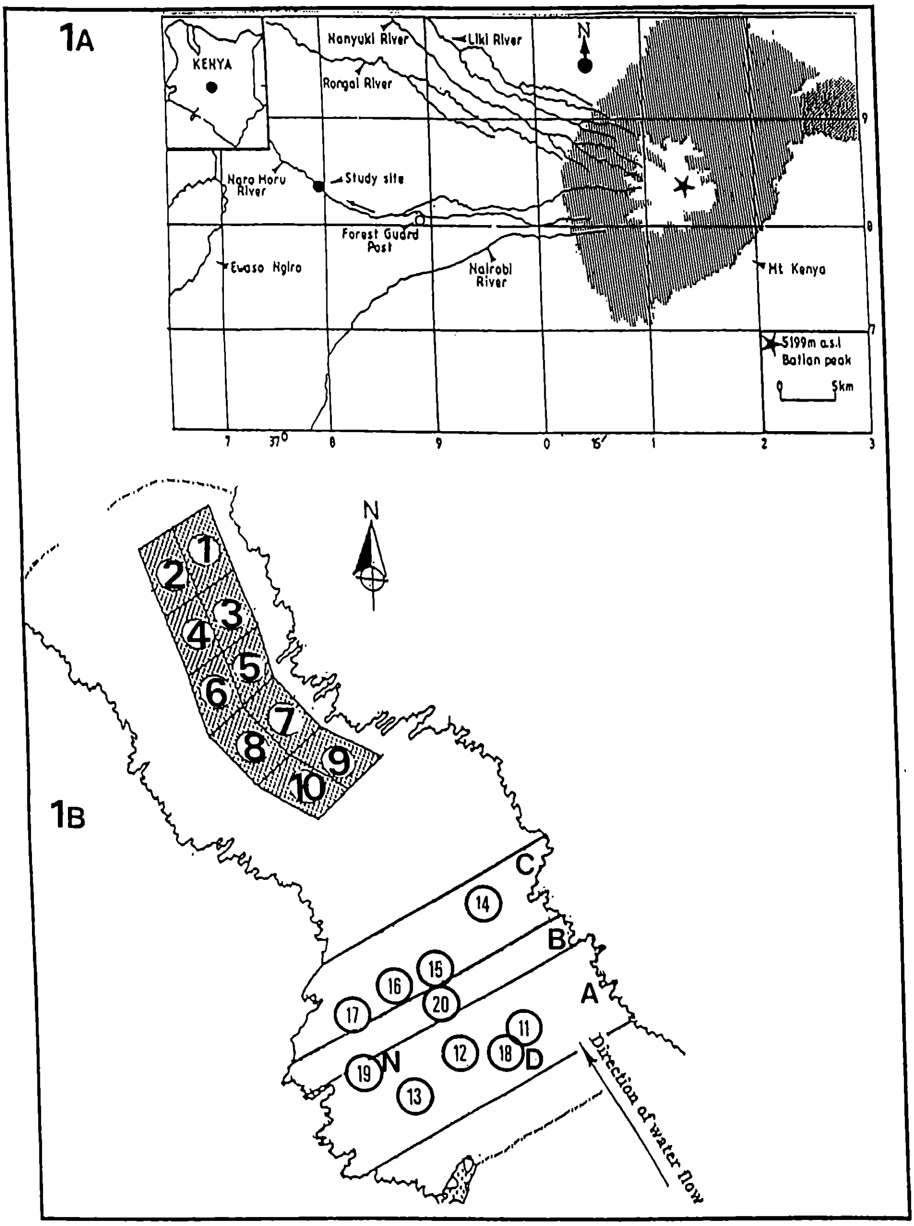

Fig. 1A: The Naro Moru River and the location of the study site.
Fig. 1B: Location of the Control and Experimental Sampling Transects (A,B & C) and subsites on the study riffle. Inset shows the actual location of the study riffle in Kenya.

1-10: Control area sampling strata
11-13: Medium short-term disturbance (MSTD) subsites
14-17: Long-term disturbance (LTD) subsites
18D & 19N: Extreme short-term disturbance (ESTD) subsites. D=Day, N=Night
20: Disturbance duration subsite

ESTD(Day) and ESTD(Night) subsites were also marked as in MSTD experiments on transect A. In these experiments, physical disturbance was induced at an interval schedule of 0, 10, 10, 20, 20, 40 and 40 minutes. One subsite for disturbance duration (DUR) experiment was similarly marked on Transect B and cumulatively disturbed from one minute to 14 minutes to simulate the effect of continuous disturbance on abundance and species richness. Long-term disturbances, in which physical disturbance was induced after every 2 - 6 weeks, involved four subsites (LTD1, LTD2, LTD3 & LTD4) set on Transect C. LTD1 and LTD4 were disturbed after 33 - 43d interval and LTD2 and LTD3 after 13 - 28d interval.

Water temperature (°C)	11.3 - 18.1
Current velocity (ms^{-1})	0.10 - 1.48
Discharge (m^3s^{-1})	0.12 - 3.57 (July - Dec. 1993)
pH	6.88 - 7.99
% canopy cover	~87 %
Length of the riffle (m)	82 m
Average width of the riffle (m)	8.4 m
Bank slope (°)	
Left orographic bank	78
Right orographic bank	74

Substrate characteristics

	Experimental area	Control area
Q_{25}	18.6	15.3
Md	40.0	32.2
Q_{75}	65.0	67.0
S_0	2.30	3.69
<0.1 mm	0.32 %	1.30 %

Subsite substrate sphericity range	0.67 - 0.72 (Disc-shaped/oblate spheroid)

Tab. 1: Chemical and physical characteristics of the Naro Moru River at the study riffle.

RESULTS

Table 1 gives the chemical and physical characteristics of the Naro Moru River at the study riffle. It indicates that the sediments in both areas were very poorly sorted, $S_o > 2.0$, according to Andrews (1983) sorting index classification in which sorting index is calculated as $\frac{1}{2}(d_{84}/d_{50} + d_{50}/d_{16})$ with d as the sediment's diameter in mm. Sediment sphericity (ψ) was determined as ($\psi = \sqrt[3]{BC / A^2}$ where A is the longest, B intermediate and C shortest axes (Krumbein, 1941). Owing to the insufficiency of taxonomic knowledge on the riverine fauna of Kenya, many mayfly specimens were assigned only to the lowest taxon within which they could be placed with certainty. The number of mayfly species in the Naro Moru River is unknown. Detailed examination of the collections showed that certain species were especially common and these included *Afronurus* sp. (49.4%), *Choroterpes (Eu.)* sp. (25.6%), *Baetis s.l.* (13.1%), *Afroptilum sudafricanum* (3.8%), *Baetis (Negrobaetis)* sp.1 (3.0%), *Baetis (Negrobaetis)* sp.2 (3.0%) and *Caenis* sp. (2.1%). This discrimination was based on the MSTD experiments in which a total of 17369 individuals were collected. The genus *Baetis (Negrobaetis)* is being recorded for the first time in Africa though having been collected from River Sigi (Usambara Mts) and from a stony stream in Morogoro, Tanzania, in 1985 and 1991 by M.T. Gillies (pers.comm.).

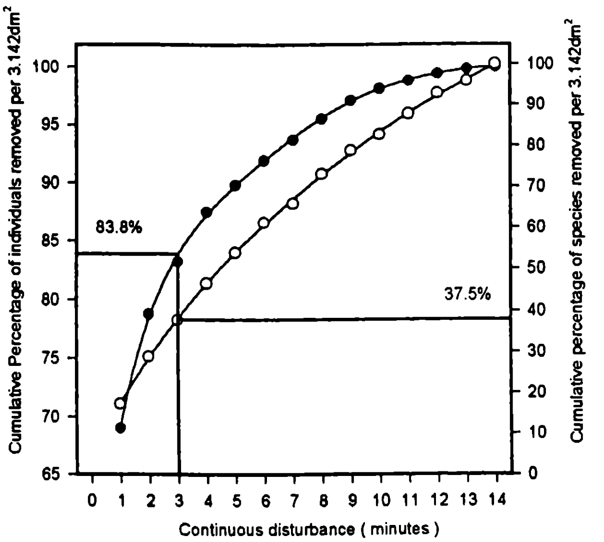

Fig. 2: Cumulative percentage curves for densities and species removed during the continuous disturbance experiments. Inside percentages indicate cumulative percentages removed for the first three minutes.

●-●-● Cumulative % densities (Ind./3.142dm^2)

o-o-o Cumulative % species richness (No. species/3.142dm^2)

Continuous disturbance had a distinct depressing effect on mayfly densities as well as species richness. Cumulatively, 83.8% and 37.5% of the number of ephemeropteran individuals and species were removed from the streambed within the first three minutes of continuous disturbance, respectively (Fig. 2). Near-complete defaunation of the disturbed subsite was evident within the 14 minutes' continuous disturbance. When all the eleven sampling occasions were considered, the number of mayfly individuals removed within the first three minutes ranged from 70.6% to 94.3%. The control site's densities and species richness showed trends contrasting the disturbed subsites which showed sharp decreases in densities but stabilized species richness (Fig. 3). Additionally, disturbance was found to have a depressant effect on the mayfly densities but species richness stabilization in the ESTD experiments (Fig. 4). In the long-term disturbances, it was found that the variations in mayfly densities were most erratic in the subsites with 11 disturbances as opposed to those

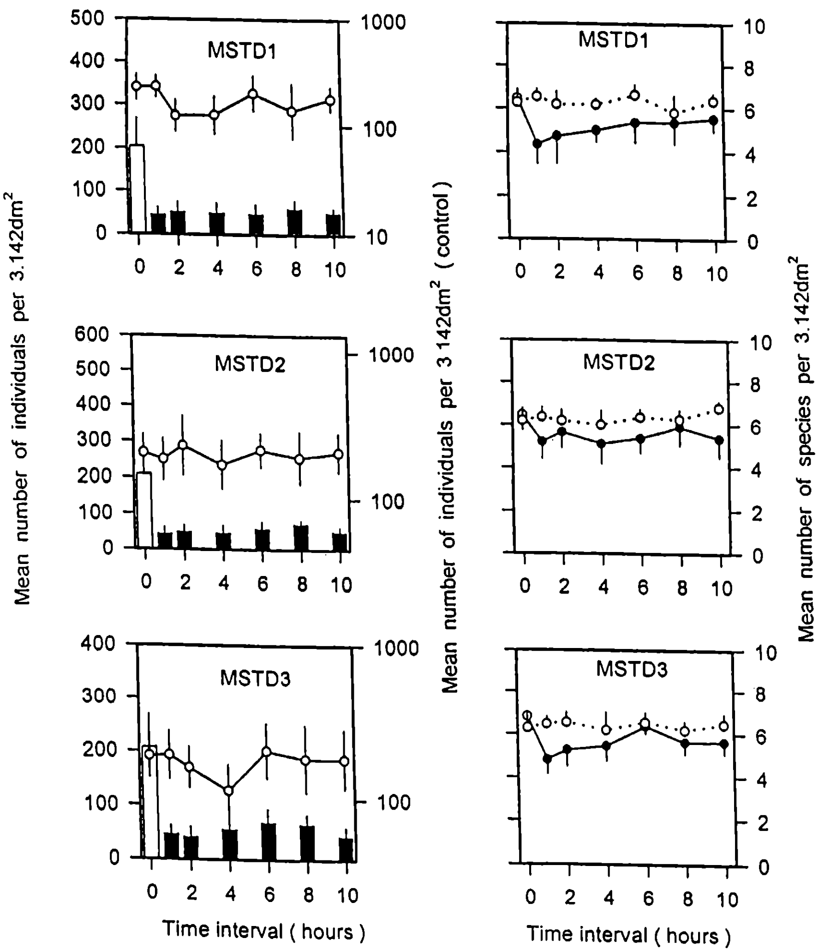

Fig. 3: Variations of the densities and species richness in the MSTD subsites and the controls. Bars indicate densities in the MSTD subsites

●-●-● Species richness (MSTD)

o-o-o Densities (control)

o o o Species richness (control)

Pre-disturbance (i.e. 0 hour) bars and dots are all open. Vertical lines: ±95%CL.

with 6 disturbances with inter-subsite density differences prominently discernible for *Afronurus* sp. (LTD1 vs LTD2, t-test = 2.99, $p<0.01$; LTD1 vs LTD3, t = 3.17, $p<0.01$; LTD1 vs LTD4, t = 3.36, $p<0.01$) and *Caenis* sp. (LTD1 vs LTD2, t = 3.09, $p<0.01$; LTD1 vs LTD3, t = 5.17, $p<0.001$).

A sequential build-up of mayfly densities and species richness for all experiments combined is depicted in Figure 5a, b and c, indicating that the Ephemeroptera community recovered fully in both density and species richness within 19d of post-disturbance (Fig. 5c) and thereafter a drastic decline in density ostensibly due to increases in water discharge (Fig. 5d).

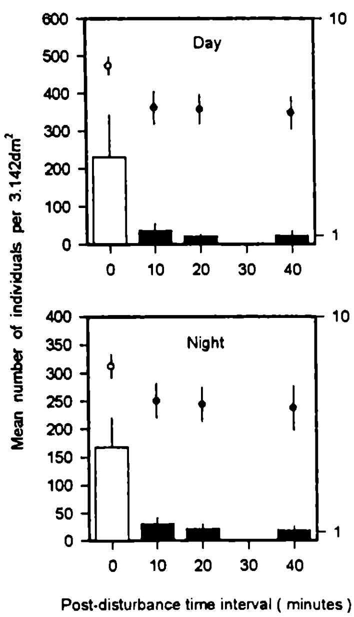

Fig. 4: Day and night variations of densities and species richness in the extreme short-term experiments. Open bars and dots indicate pre-disturbance density and species, respectively. Vertical lines: ±95%CL.
■ Densities (Ind./3.142dm^2)
● ● Species richness (No. species/3.142dm^2)

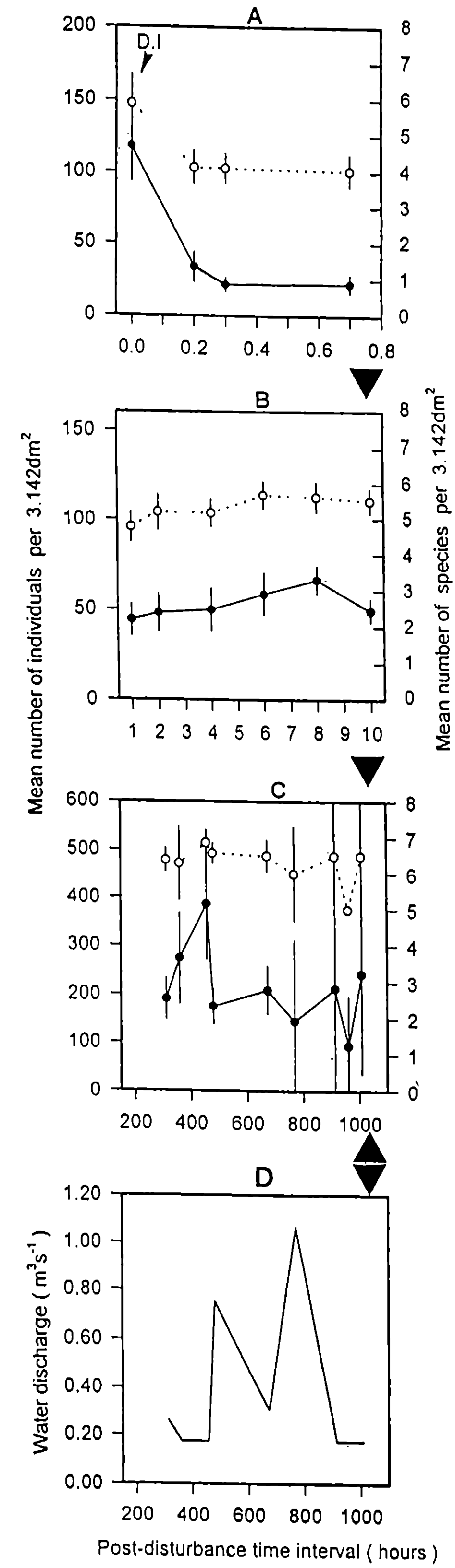

Fig. 5: Sequential presentation of all experiments over the post-disturbance intervals (A, B, C). D relates discharge with the trends shown in C. D.I = Disturbance inducement. Vertical lines: ±95%CL.
●-●-● Densities (Ind./3.142dm^2)
O-O-O Species richness (No. species/3.142dm^2)

DISCUSSION

Natural communities of co-occurring species in lotic ecosystems are, to a lesser or greater degree, dynamic in that the relative abundances of individual species change with time and space. This dynamism could be viewed in terms of life history traits coupled with other stochastic and deterministic environmental processes. Disturbance is one of the stochastic events that shape community structure and its impact could be explored by turning stones (Boulton *et al.* 1988) and kicking and raking (Marchant *et al.* 1991). The initial physical disturbance intensity normally involves dramatic ephemeropteran abundance and diversity reductions (Mathooko 1995). Maximum densities of mayflies were found on the disturbed subsites after 19d of post-disturbance, indicating a fast recolonization process. This fast recolonization process might be due to drift processes. Osborne (1983) reported that a heterotrophic epilithic community resembles that of the undisturbed substrates within 13d. Moreover, artificial substrates used in the sediment of the Naro Moru River were maximally recolonized after about 10d (Mathooko & Mavuti 1992). Short-term disturbances normally maintain periphyton biomass at low levels. In the DUR and ESTD experiments, no recovery to the pre-disturbance density and species richness occurred. This might be explained by the short time lag which could not allow the fauna to re-establish itself. Furthermore, recolonization of MSTD subsites within 1 to 10 hours of post-disturbance may not be as a result of biofilm development since no substantial development could have taken place within such a short time. Thus it may be plausible that drifting organisms may take advantage of the relatively bare subsites. Nevertheless, physical disturbance is a factor with a depressant effect on mayfly densities depending on the disturbance interval.

ACKNOWLEDGMENTS

I am deeply indebted to Dr P.E. Schmid for his constant stimulating discussions on the subject and to the Naro Moru River Lodge management for allowing an easy access to the study site. I thank Jamhuri Nthenge for the many hours of assistance in the field. I also thank the Biologische Station Lunz (Austria) and Egerton University (Kenya) for logistic support. This study was fully funded by the Österreichischer Akademischer Austauschdienst (ÖAD) through the Nord-Süd Dialog Programm (EH-Projekt 894/92).

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