Structure and composition of benthic macroinvertebrates of a tropical forest stream, River Nyamweru, western Uganda

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Abstract

Benthic invertebrates from River Nyamweru, a tropical forest stream in western Uganda were sampled bimonthly between April and December 1997 using a modified Hess Sampler. A total of 3708 benthic fauna from thirteen taxonomic orders were collected. Benthic samples were dominated by Diptera (mainly Chironomidae) representing over 60% of all the organisms, followed by Ephemeroptera. Benthic invertebrate densities ranged from 63 ± 9.03 organisms/m^2 to 300 ± 33.36 organisms/m^2, with higher densities occurring during the dry season and lower densities during the wet season. The benthic community structure in River Nyamweru reflected mainly collectors and scrapers as the most important groups (83%), while predators were very rare (3.1%). River discharge influenced benthic abundance, with more invertebrates at lower discharge and fewer invertebrates at higher discharge. The applicability of the River Continuum Concept to tropical forest stream situation is discussed.

Entre avril et décembre 1997, on a prélevé deux fois par mois, avec un collecteur de Hess modifié, des échantillons d'invertébrés benthiques dans la rivière Nyamweru, un cours d'eau forestier tropical de l'ouest de l'Ouganda. On a récolté un total de 3708 organismes benthiques appartenant à treize ordres taxonomiques. Les échantillons benthiques étaient dominés par les Diptères (principalement des Chironomides) qui représentaient plus de 60% de tous les organismes, suivis par les Ephéméroptères. La densité des invertébrés benthiques variait de 63 ± 9,3 organismes/m^{2}à 300 ± 33,36 organismes/ m^2, la plus haute densité s'observant en saison sèche, et la plus faible en saison des pluies. La structure de la communauté benthique de la rivière Nyamweru révèle que les groupes les plus importants sont les récolteurs et les racleurs (83%) tandis que les prédateurs sont très rares (3,1%). Le débit de la rivière influence l'abondance benthique, il y a plus d'invertébrés quand le débit est faible et moins quand le débit est fort. On discute de l'applicabilité du Concept du Continuum Riverain à la situation d'une rivière forestière tropicale.

Introduction

Over the past two decades, significant progress has been made in understanding the structure and functioning of small tropical rivers (Covich 1988; Cressa *et al*. 1993 ; Jackson & Sweeney 1995; Matagi 1996). However, there are still not many studies for meaningful comparisons. This gap of information is common whatever the approach used (descriptive, taxonomical, physiological, population dynamics, community or ecosystem level, Cressa *et al*. 1993). Information on the structure and functioning of small streams is necessary for the proper management and conservation of fresh water resources in these ecosystems. It is also necessary for drawing up monitoring programmes of these ecosystems to preserve and conserve their biodiversity. Ecological concepts such as the River Continuum Concept (RCC) have been formulated to explain and predict patterns in river ecosystems, but these have been found to be valid for temperate regions (Vannote *et al*. 1980).

In Eastern Africa, very few studies have been done on stream benthic fauna. For instance, Williams & Hynes (1971) surveyed benthic fauna of some streams from Mt. Elgon, while Mathooko (1995) looked at colonization of artificial substrates by benthos in the Naro Moru River in Kenya. Other studies are either in their infancy or not published at all. In order to increase our knowledge on the structure and functioning of tropical river ecosystems, an intensive sampling of benthos was conducted on a tropical forest stream, the River Nyamweru, in western Uganda between April and December 1997. This investigation focused on the structure and taxonomic composition and the temporal distribution of benthic macroinvertebrates.

Study area and methods

This study was conducted on River Nyamweru, located in the tropical humid Maramagambo Forest, western Uganda (0°17′−0°36′ S and 29°49′−30°07′ E). The catchment area is approximately 440 km^2 and drains into Lake Edward. Because the river is located in a forest, there is very little human impact and its biological characterization can be used as background reference for streams located in humid tropical zones. The riparian vegetation consists of the dominant tree species of Maramagambo Forest, namely *Cynometra alexandri*, *Parinari excelsa*, *Sapium ellipticum*, *Carapa grandflora* and *Newtonia buchananii*.

The River Nyamweru is approximately 35 km long and some of its morphometric variables are given in Table 1. Precipitation during the sampling period totalled 884 mm, falling in two periods, March–May and September–December. However, this study coincided with a year where precipitation was unusually high between September and December, owing to the *El Niño* weather phenomenon around the study area. Accordingly, the seasonal variation in river discharge follows the precipitation regime (Fig. 1). Owing to significant variations in precipitation, morphometric variables (depth, width, water velocity and sediment load) occurred at a fast pace, with a consequent effect on the benthic community.

Table 1. Some morphometric variables of the River Nyamweru (mean annual values for width, depth, velocity and discharge at the sampling site)

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Variable	Value	Range (n = 9)
Width (m)	6.3	3.2–8.1
Depth (cm)	86.0	22.1–200.0
Velocity (cm/sec)	94.1	33.0–195.2
Discharge (cm^3/sec)	85.3	4.21–148.76
Length (km)	35.2	–

Figure 1 Seasonal variation. in discharge and precipitation during the study period (April–December 1997).

Macroinvertebrates were collected bimonthly from April to December 1997. Sampling during the month of October became impossible mainly due to flooding (caused by the *El Niño* weather phenomenon). Benthic samples were collected using a modified Hess Sampler (0.049 m^2; 100 µm mesh size) and replicate samples were always collected covering all the heterogeneous habitats of the river (pools, riffles, under vegetation and debris). For comparison purposes, two habitat types of pool and riffle regions were always sampled each month. All samples were preserved in 4% formalin and transported to the laboratory, where they were sorted and identified to taxonomic groups and functional feeding groups according to Merritt & Cummins (1978).

Results

Composition of benthic invertebrates

Between April and December 1997, a total of 3708 benthic invertebrates from thirteen taxonomic orders was collected in River Nyamweru. The most abundant taxa in terms of relative frequency were Chironomidae (>40%), followed by Ephemeroptera and Ceratopogonidae

(13.11% and 10.92%, respectively; Table 2). It is thus clear that at the high taxonomic level, individuals of benthic invertebrates in River Nyamweru belonged to the Diptera. Within the Ephemeroptera, *Baetis* occurred at a higher relative frequency than other genera. Other important representatives of benthic invertebrates were Coleoptera, Plecoptera, Oligochaeta, Trichoptera, Simulidae, Ostracoda and Collembolla (Table 2). Rare ones included Turbellaria, Cyclopoida, Harpacticoida, Nematoda and Hemiptera, whose relative frequency was less than 1% for each. Statistical analyses showed significant differences in numbers of benthic invertebrates between samples from pool and riffle habitats of the River Nyamweru (*t*-test; $t_{(18)} = 3.02$, $P < 0.05$; Table 2), with pool habitats having more than riffle habitats. Nevertheless, there were no marked taxonomic differences in species composition between the two habitat types of pool and riffle, as most of the organisms appeared in both habitats.

Table 2. Total number (*n*) and percentage (%) of benthic invertebrates caught by a modified Hess Sampler in pool and riffle habitats in the River Nyamweru (April–December 1997)

Table 2 Total number (n) and percentage (%) of benthic invertebrates caught by a modified Hess Sampler in pool and riffle habitats in the River Nyamweru (April–December 1997)

	Pool		Riffle	
Taxon	n	%	n	%
Turbellaria	6	0.34	0	0
Nematoda	15	0.72	15	0.90
Oligochaeta	69	3.30	72	4.34
Cyclopoida	6	0.34	0	0
Harpacticoida	12	0.57	15	0.90
Ostracoda	69	3.30	33	1.99
Collembolla	63	3.01	21	1.27
Ephemeroptera				
Baetidae	87	4.16	36	2.17
Caenidae	45	2.15	24	1.45
Other Ephemeroptera	180	8.60	114	6.87
Plecoptera	45	2.15	42	2.53
Hemiptera	15	0.72	15	0.90
Coleoptera	102	4.87	54	3.26
Trichoptera	66	3.15	33	1.99
Diptera				
Simulidae	39	1.86	60	3.62
Ceratopogonidae	225	10.75	180	10.85
Chironomidae	858	40.97	747	45.03
Other Diptera	159	7.59	162	9.76
Miscellaneous	13	0.58	11	0.71

Temporal variation of benthic invertebrate community

Mean (±SD) benthic densities of macroinvertebrates ranged from 63 ± 9.03 organisms/m^2 to 308 ± 33.36 organisms/m^2, with an overall mean of 150 ± 15.63 organisms/$m^{2.}$ In both pool and riffle habitats, the highest densities were obtained during the dry months of July to September, while samples from wet months (April–May and October–December 1997) recorded low benthic densities (Fig. 2). This shows that macroinvertebrate fauna abundance in River Nyamweru shows seasonal variation, with taxa alternating their abundance throughout the year according to rainfall patterns. Benthic densities varied among taxa. For example, Diptera had densities ranging from 100 ± 23.52 organisms/m^2 to >1000 ± > 321 organisms/m^2; Trichoptera and Plecoptera ranged between 0 and 200± 8.23 organisms/m^2, while Ephemeroptera ranged from 30 ± 2.42 to 500 ± 56.93 organisms/$m^{2.}$ In all these groups benthic densities were always higher in the dry season than in the wet season.

Figure 2 Monthly variations. in total benthic macroinvertebrate densities in the River Nyamweru during the sampling period (April–December 1997). Note that October data are missing because it became impossible to sample due to the *El Niño* weather phenomenon.

Community structure

According to the River Continuum Concept (RCC), it is important to group benthic invertebrates into functional feeding groups in order to study the community organization. The separation into functional groups was made using categories established by Merritt & Cummins (1978). The composition of the macroinvertebrates according to functional feeding groups is shown in Fig. 3. Collectors and scrapers are the most important group (82.3%), while shredders and predators are scarce (5.7% and 3.1%, respectively) in the River Nyamweru. The most important collectors were Chironomidae, while scrapers were dominated by Ephemeroptera, mainly *Baetis*. Seasonal patterns in macroinvertebrate abundance did not affect the functional feeding groups because the numbers of the most dominant group (collectors/scrapers) were always higher in both the wet and dry seasons.

Figure 3 Percentage composition. of functional feeding groups in River Nyamweru, western Uganda.

Discussion

The River Nyamweru exhibited a great diversity of benthic invertebrates. A large number of invertebrate orders were represented in the benthic samples. The mean density of macroinvertebrates (for both pool and riffle habitats combined) is however, low (150 organisms/m^2) as compared to other tropical streams, where benthic densities can reach as high as 1409 organisms/m^2 and even 5482 organisms/m^2 (Dudgeon 1988; Cressa 1994; Tockner 1994). Either the density of benthic invertebrates is highly variable, matching the highly diverse habitats of tropical streams, or there are not enough data on humid tropical forest streams for comparison.

Seasonal variation in benthic abundance of fauna in the River Nyamweru showed high numbers in the months of July–September (dry season) and low numbers in April–June and November–December (wet season). This is in contrast to results obtained elsewhere (Mathooko & Mavuti 1992; Harrison & Hynes 1988). These authors reported high benthic abundance during the wet season and low abundance during the dry season while working on high altitude streams in Kenya and Ethiopia, respectively. It is however, important to note that 1997 was characterized by unusually heavy rainfall and floods in and around the study area between late September and early December (due to the *El Niño* weather phenomenon). This significantly increased the discharge in the River Nyamweru which could have swept away most of the benthos and would-be substrates (gravel and boulders that are holdfasts for benthos) further downstream of the study site, leading to the reduction of habitat for benthos and hence their low numbers in the wet season. The modification of invertebrate abundance by river discharge was mentioned earlier by Sagar (1986), who found flows in excess of 400 m^3/s disrupting invertebrate communities.

In temperate latitudes, benthic fauna density fluctuations are usually explained by loss of organisms through flushing during spring thaw, or summer emergence of insects (Brittain & Eikeland 1988). However, it appears that in tropical climates other factors intervene, for example, Hynes (1975) observed a marked reduction in the benthos of a Ghanaian Stream during the dry season because of the interruption of flow, while Bishop (1973) explained fluctuations of densities in a Malayan river by a destructive recurrence of flood. In the River Nyamweru, there was marked flooding between October and November 1997. This could have had disruptive effects on the benthic communities and abundance.

The RCC suggests that orderly and predictable changes in ecosystem structure and function occur from head waters to the mouth of rivers (Vannote *et al*. 1980). This concept has been widely used to explain longitudinal gradient in streams (Ward 1989), but its generalizations and applicability to other systems located outside the temporal and boreal regions of North America have been questioned (Dudgeon 1984; Statzner & Higler 1985; Bunn 1986; Tockner 1994). According to the RCC, on sampling site (second-order streams but not head water), the composition of the benthic fauna would be expected to be approximately: collectors (50%), shredders (30%), scrapers (5%) and predators (15%) and with low density and diversity. However, the River Nyamweru was observed to be different and would correspond to a fourth/fifth-order stream (shredders are replaced by scrapers). According to Vannote *et al*. (1980) , first- and second-order streams are usually characterized by low diel temperatures of less than 10°C, high relative diversity of soluble organic compounds, low biotic diversity and a high coarse particulate organic matter to fine particulate organic matter ratio (CPOM/FPOM). Although not all these parameters were considered in this study, present findings indicate high diel temperatures and high biotic diversity. The CPOM/FPOM is expected to be low as there is no greater distinction in sediment structure along the river course. It should also be noted that the River Nyamweru does not possess the morphometric characteristics of a first- or second-order stream as stated in the RCC. Therefore, this study does not support the RCC. Lastly, it is important to note that mainly young instars of invertebrates were collected, indicating that fish and shrimps could be a regulating factor, as they were abundant at the sampling site. However, this is a different aspect altogether, which would need its own investigation as it was not among the objectives of this study.

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References

- *Bishop, J.E. 1973. Limnology of a Small Malayan River Sungai Gombak. Dr Dr W. Junk. The Netherlands.*
    - CrossRef
- *Brittain, J.E. & Eikeland, T. 1988 Invertebrate drift: a review. Hydrobiologia, 166, 77 93.*
    - CrossRef,
    - Web of Science®
- *Bunn, S.T. 1986 Spatial and temporal variation in the macroinvertebrate fauna of streams of the northern Jarrah forest, Western Australia: functional organisation. Freshwater Biol., 16, 621 632.*

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    - References
    - Web of Science®
- *Covich, A.P. 1988 Geographical and historical comparisons of neotropical streams: biotic diversity and detrital processing in highly variable habitats. J. N. Am. Benthol. Soc., 7, 361 386.*
    - CrossRef,
    - Web of Science®
- *Cressa, C. 1994 Structural changes of the macroinvertebrate community in a tropical river. Verh. Internat. Verein. Limnol., 25, 1853 1855.*
    - Web of Science®
- *Cressa, C., Vasquez, E., Zoppi, E., Rincon, J.E., Lopez, C. 1993 Aspectos generales de la Limnologia en Venezuela. Interciencia, 18, 237 248.*
    - Web of Science®
- *Dudgeon, D. 1984 Longitudinal and temporal changes in community organisation in Lam Tsuen River, Hong Kong. Hydrobiologia, 111, 207 217.*
    - CrossRef,
    - Web of Science®

- *Dudgeon, D. 1988 The influence of riparian vegetation on the functional organisation of four Hong Kong stream communities. Hydrobiologia, 179, 183 194.*
    - CrossRef,
    - Web of Science®
- *Harrison, A.D. & Hynes, H.B.N. 1988 Benthic fauna of Ethiopian streams and rivers. Arch. Hydrobiol. Supplement , 81, 1 36.*
- *Hynes, J.D. 1975 Annual cycles of macroinvertebrates of a river in southern Ghana. Freshwater Biol., 5, 71 83.*

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    - References
    - Web of Science®
- *Jackson, J.K. & Sweeney, B.W. 1995 Present status and future directions of tropical stream research. J. N. Am. Benthol. Soc., 14, 5 11.*
    - CrossRef,
    - Web of Science®
- *Matagi, S.V. 1996 The effect of pollution on benthic macroinvertebrates in a Ugandan stream. Arch. Hydrobiol., 137, 537 549.*
    - Web of Science®
- *Mathooko, J.M. 1995 Colonisation of artificial substrates by benthos in a second-order high altitude river in Kenya. Hydrobiologia, 308, 229 234.*
    - CrossRef,
    - Web of Science®
- *Mathooko, J.M. & Mavuti, K.M. 1992 Composition and seasonality of benthic invertebrates, and drift in Naro Moru River, Kenya. Hydrobiologia, 232, 47 56.*
    - CrossRef,
    - Web of Science®
- *Merritt, R.W. & Cummins, K.W. 1978 An Introduction to the Aquatic Insects of. North America. 2nd edn. Kendall/Hunt, Dubuque, Iowa.*
- *Sagar, P.M. 1986 The effects of floods on the invertebrate fauna of a large unstable braided river. NZ J. Mar Freshwater Res., 17, 377 386.*
    - CrossRef
- *Statzner, B. & Higler, G. 1985 Questions and comments on the River Concept. Can. J. Fish. Aquat. Sci., 42, 1038 1044.*
    - CrossRef,
    - Web of Science®
- *Tockner, K. 1994 Ecology of Rwandesian Rivers (Central Africa). International Conference on Tropical Limnology, Salatiga, Central Java. (Abstract).*
- *Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., Cushing, C.E. 1980 The River Continuum Concept. Can. J. Fish. Aquat. Sci., 37, 130 137.*
    - CrossRef,
    - Web of Science®
- *Ward, J.V. 1989 The four-dimensional nature of lotic ecosystems. J. N. Am. Benthol. Soc., 8, 2 8.*

- CrossRef,
- Web of Science®
- *Williams, T.R. & Hynes, H.B.N. 1971 A survey of the fauna of streams of Mt. Elgon, East Africa, with special reference to the Simulidae (Diptera). Freshwater Biol., 1, 227 248.*

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