USE OF BENTHIC MACROINVERTEBRATES AS INDICATORS OF WATER QUALITY IN RIVER NJORO, KENYA

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ABSTRACT

Unsustainable anthropogenic activities, including intensive agriculture and grazing along River Njoro has resulted in the deterioration of river water quality. This is mainly through runoff and increased effluent discharge to the river. The river is the most important source of freshwater for the riparian communities and Lake Nakuru, a Ramsar site. In its middle reaches, the water quality is gradually declining. The study was done in order to determine the water quality in the middle reaches of River Njoro using benthic macroinvertibrates assemblage as an indicator. The assemblage of benthic macroinvertebrates was compared with selected physicochemical variables along the middle reaches of River Njoro during both wet and dry seasons. Ten sites in River Njoro were established and sampled. Kenyatta and Ngata had significantly ($p< 0.05$) high temperatures than all the upstream sites. Nitrates, ammonia and total nitrogen concentration were more than four times higher at Bora than at both Confluence and Njoro over the dry season. At Canners Up and Bora, total phosphorus concentration was more than double that at Confluence and Kenyatta. Higher richness of benthic macroinvertebrate (mean=28.6 ± 5.96) was recorded at Njoro. At Egerton, Canners Up and Canners Down, the abundance of macroinvertebrates in the dry season was more than ten times less that in the wet season. Chironomidae, Oligochaete, *Moina sp* and Cyclopoidae were characteristic of the impacted sites. *Potamon sp*, *Orthotrichia sp*, *Ecdyonurus sp* and *Catenula sp* were present at the upstream sites but absent from all sites receiving effluents. This study shows that only tolerant taxa inhabit the impacted sites especially over the dry season.

Key words: physicochemical parameters, anthropogenic activities, tolerant taxa, middle reaches, wet season, dry season, impacted sites, effluents.

INTRODUCTION

Since the development of the Saprobian index nearly a century ago, practitioners of bio-assessment have accumulated information on the effects of anthropogenic stress on aquatic communities (Cairns 2003). Consequently, it has been observed that human disturbance alters key attributes of aquatic eco-systems such as water quality, habitat structure, hydrological regime, energy flow and biological interactions (Karr and Dudley 1981; Karr 1999; Emery *et al.* 2003). For rivers, this is particularly expected in urbanizing rural areas because there is no municipal infrastructure to handle industrial and domestic wastes. In many cases, such wastes are usually discharged into a local stream with the hope that they will be flushed downstream with minimum impact on local environments and bio-diversity. Unfortunately, this is usually not the case as point source pollution from effluent discharges influence water chemistry and habitats in ways that reduce their integrity (Odum 1975).

Water quality degradation as a result of point source pollution further impacts the ecological integrity of streams because they are small relative to the surrounding landscape and the number of users (people, livestock and factories) who depend on them directly. Although Odum (1975) gives expected patterns in stressed eco-systems, his examples are based on observed responses in temperate systems. Little information exists on patterns of response to stress by tropical rivers especially in relation point source pollution.

By examining patterns in the response of assemblages of benthic invertebrates to potential stressors, especially nutrients and suspended material, associated with point source discharges, it may be possible to assess the extent to which pollution alters the physicochemical characteristics and the structure of biological communities in stream eco-systems. This approach has never been used before in East African streams despite the need to assess the biological integrity of streams in rural areas.

In the River Njoro watershed, a majority of local people depend on direct extraction from stream for their water supplies. This, combined with reducing water flows associated with reduced base flow over the dry season, is expected to worsen the impacts of point source pollution. This is because at certain times of the year, base flow downstream point-source discharges, composes almost completely of effluent. As rains set in April and May, usually the flow of the river is associated with floods (Shivoga, 2001). It is necessary to determine how these seasonal variations in stream flow interact with point source pollution to alter water chemistry and structure of biological communities. Once this is known, environmentalists and water resource managers can put in place measures to reduce impact, improve water quality and conserve biological diversity on the middle reaches of tropical rivers.

This study was carried out to investigate the influences of seasonality and point source effluent pollution on water chemistry and the structure of benthic invertebrates in the urbanizing middle reaches of River Njoro. The objectives were to determine, in the middle reaches of River Njoro:

i. The water quality using macroinvertibrates assemblage as an indicator

ii. The physicochemical characteristics of water over the dry and wet seasons,

iii. The structure of benthic invertebrates over the two seasons, and

iv. How effluents influence physicochemical and biological characteristics of River Njoro over the two seasons

MATERIALS AND METHODS

Study Area

River Njoro is 50 km in length and drains a watershed that lies within latitudes 0^0 15's and 0^0 25' and between longitudes $35^0$50'and $35^0$05'E. Its watershed is approximately 200 sq.km. It originates in the Eastern Mau hills, flows through small upstream villages, the urbanizing middle reaches around Egerton University and Njoro town and finally empties into Lake Nakuru which is widely famous for its population of flamingoes. The river consists of two main tributaries: Little Shuru and mainstream Enjoro that join around Egerton University. The general topography of the catchments ranges from the hilly uplands of Eastern Mau escarpment to the nearly flat terrain around Lake Nakuru. The altitude ranges from about 3000 m above sea level (m.a.s.l) at the source of the river to about 1700 m a.s.l. at its mouth. The average rainfall is 1200 mm distributed "trimodally" with peaks in April, August and November (Karanja *et al.,* 1989). The soils in the catchments are predominantly volcanic, clay-loam except near the lake where silt clay is found (Karanja *et al.*, 1989). The river itself is structured in a typical pool-riffle sequence with pre-dominantly soft substrata in the pool area and bedrock in riffle sections (Bretschko 1995).

This study focused on the urbanizing middle reaches of the river after the confluence around Egerton University (at 2300 m a.s.l) and Ngata (2000 m a.s.l). Sites for sampling were chosen to represent points along the river before, at and after areas of point discharges of effluents. Consequently, Confluence, Mary-Joy Egerton University, Canners Up and Canners Down, Bora Milk, Njoro Bridge, Kenyatta and Ngata were chosen for routine sampling. Confluence represented the river before effluent discharges. Egerton University, Canners Up and Canners Down, and Bora Milk are points along the river receiving effluents from Egerton University, Canning factory and Bora milk factory. Njoro Bridge, Kenyatta and Ngata were chosen to represent conditions down stream of impact and to test how fast effluents were assimilated.

Physico-chemical Characteristics

Routine monthly monitoring of the physicochemical characteristics of the river was done at each site for five months. On each occasion, temperature (^{0}C), dissolved oxygen (%), pH and conductivity (µs/cm) were measured using a Jenway electrochemical analyser with probes for each parameter. Water samples were collected in rinsed plastic bottles, kept in a cool box and delivered to the water quality-testing laboratory in

Lake Nakuru where they were analysed promptly or kept refrigerated for analysis the following morning. For each sample, Total Suspended Solids (TSS), Total Organic Carbon (TOC), ammonium nitrogen (NH_4-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N), organic nitrogen (ON) and total nitrogen (TN) were determined. Orthophosphate phosphorus (PO_4-P) and total phosphorus (TP) were also analysed for each sample. All analysis followed standard methods developed by the American Public Health Association (APHA, 1998).

Benthic Macroinvertebrates

Benthic fauna were sampled with a modified Hess sampler (sampling area=2.7 dm^2; net mesh size=100 micrometers) and sorted and counted in the laboratory at Egerton University. The mean abundance (individuals.dm^{-2}), species diversity (Shannon-Weaver index), species richness (Margalef's index) and dominance were calculated for each site and sampling occasion for the study period. Owing to the lack of taxonomic keys for the Kenyan stream fauna, most specimens were assigned only to the lowest taxon within which they could be placed with certainty. Consequently, only a few could be identified to species level. Data were analysed using one-way ANOVA, multiple regression and correlation analyses of the window based STATISTICA®, statistical software (Statsoft, 2001).

RESULTS

Physico-chemical parameters

A summary of the physico-chemical factors for the sites sampled in the middle reaches of River Njoro are shown in Table 1. Generally, the river appears to have distinct physicochemical characteristics in the dry and wet seasons with more influence of point source pollution in the dry than wet seasons. For example, it is warmer over the dry than wet season. In both seasons, there is a general trend of increasing temperature downstream. As such, the highest (19.3±0.5^{0}C) and the lowest (16.2±1.8^{0}C) mean water temperature were recorded at Ngata and Confluence, the lower and upper most sites respectively. The low temperatures observed between Confluence and Njoro Bridge is likely to be a direct consequence of shading by streambank vegetation because the river here runs through large-scale farms whose riparian zones are not impacted unlike Kenyatta and Ngata.

Likewise, conductivity showed an observable difference between the dry and wet seasons along the river. During the wet season, all the sites showed low mean conductivities which did not differ significantly between sites ($p>0.05$). In contrast all sites had elevated conductivities during dry season. The highest (266± 7.03µs/cm) and lowest (169.5±18.34 µs/cm) mean conductivities were recorded at Bora and Confluence during the dry season. It is important to note that sharp rises in conductivity started at the Egerton sewage discharge point and peaked at Bora. This is the stretch that is impacted by effluents from Egerton University, Njoro Canners and Bora Milk factories.

Although there were higher mean pH values along the river during the dry than wet seasons, there were no significant differences between seasons and sampling sites ($p>0.05$). Generally, Njoro River is saturated with dissolved oxygen. It is interesting to note that all sites, even those receiving effluents had saturation values above 100%. Pattern of variation between sites in Nitrogen nutrients shows a close association with effluent discharge. With the exception of Kenyatta, all sampling sites recorded higher mean NH_4-N concentrations during the dry season. The highest (3.13±0.92mg/l) and the lowest (0.01±0.02mg/l) were recorded at Bora and Mary-Joy respectively. Concentrations recorded at Bora were significantly higher than those of other sites ($p=0.000$) although Egerton University and Canners Downstream had values higher than those at Confluence by a factor of ≈ 2.

It is interesting to note that Bora recorded values as high as 10.12 mg/l NH_4-N which is responsible for the variation exhibited by its S.E. Egerton University seems to contribute the highest concentration of nitrites. A mean of 0.21±0.02mg/l was recorded here during the dry season and this was significantly higher than other means (all < 0.05mg/l) recorded along the river ($p=0.002$). Bora recorded the highest mean NO_3-N concentration (0.37±0.11mg/l) which is almost a double increase in concentration compared to Canners-Downstream which is immediately upstream of this site. Downstream at Njoro, the levels fell sharply to 0.09±0.11mg/l. This represents close to 300% drop in NO_3-N concentration. Likewise, the highest organic (4.40±0.62mg/l) and Total Nitrogen concentration (mg/l) were recorded at Bora, although they don't drop sharply at Njoro Bridge as NO_3-N. These elevated concentrations were recorded during the dry season at which time the site was significantly different in nitrate concentrations from all other sites (p=0.000). In contrast, differences between sites over the wet season were not significant (p=0.05).

Patterns of variations between sites in mean concentrations of Phosphorous nutrients followed that of Nitrogen (Table 1). The highest (mean=0.31±0.11mg/l) PO_4-P concentration was recorded at Bora Milk during the dry season. Likewise, Bora recorded high mean TP concentration (0.51±0.12mg/l) during the wet season although this was similar to Canners Upstream. This was almost double the mean values recorded at both Confluence (0.25±0.12mg/l) and Kenyatta (0.25±0.12mg/l).

Generally, Njoro River has clearer water during the dry than wet seasons. There was a significant difference in mean Total Suspended Solids (TSS) concentration between the dry and wet seasons at all sites (p=0.00) except at Ngata (p>0.05). High values were recorded in the impacted sites of Egerton University, Canners and Bora Milk but lower values were recorded at Confluence and the two downstream sites (Njoro Bridge and Kenyatta). Suspended and dissolved organic matter (measured as Total Organic Carbon) were observed to be highest (172±48.6mg/l and 128.45±0.37mg/l) at Njoro bridge during both dry and wet seasons.

Benthic macro invertebrates

Table 2 summarizes data on benthic macroinvertebrates. Seasonal variations in the abundance (individuals per square decimetre = indiv/dm^2) of macroinvertebrates show that high means were recorded during the dry season. Kenyatta recorded a mean of 109.32±29.6 indiv/dm^2. During the wet season, the mean abundance (53.5±41.9 ind/dm^2) was about half that of the dry season at this site. The highest difference in abundance of macroinvertebrates however was observed at Egerton University. Here, 105.9±29.6 ind/dm^2 was recorded during the dry season and a phenomenal 5.06±4.88 ind/dm^2 in the wet season. Similar but less disparities were observed at Canners Upstream and Downstream. With the exception of Kenyatta, all sites showed high mean richness values in the dry season (Table 2). The highest mean richness (28.60±5.96) was recorded at Njoro Bridge which was twice as high as the value recorded at Egerton University. Likewise, the highest mean diversity of benthic macroinvertebrates (0.84±0.08) was recorded at Njoro while the lowest (0.33±0.11) was recorded at Egerton during the dry and wet seasons respectively. High mean dominance values were recorded at Egerton University and Canners Downstream (0.41±0.07).

In general, macroinvertebrates did not discriminate sites as clearly as physicochemical parameters. This is more so when the total number of taxa recorded at each site is considered (Table 2). The highest cumulative number of macroinvertebrate's taxa was at Egerton University, followed by Confluence, the least impacted site. However, when the number of taxa in the major groups i.e. Diptera, Coleoptera, Ephemeroptera and Trichoptera and other groups (e.g. Oligochaete worms, Crustacea and Mollusca) are considered, the effects of effluent discharge become clearer. For example, the highest number of Dipteran taxa, the insect order considered to be most tolerant to pollution, was recorded at Egerton University (10), Canners-Downstream (9) and Bora. High Coleoptera taxa were also recorded at Egerton University. In contrast, the lowest number of taxa belonging to the orders Trichoptera and Ephemeroptera were recorded at Egerton University and Canners-Down respectively.

Specifically, *Heptagenia sp.* and *Ecdyonurus sp.* were present only in samples collected from Confluence. *Baetis sp.* was present in samples from all sites. However, it was less abundant at Canners and Bora Milk. *Cloeon sp.* was particularly abundant at Bora and appeared to favour polluted sites. Among the Trichoptera, *Orthotrichia sp.* and Limnephilidae were present only at Confluence. *Lepidostoma hirtum* (Fabricius) was present at Bora and Njoro. However, only one individual was collected from Bora Milk during the wet season and it is likely that it was brought as drift to the site. Phryganeidae and Sericostomatidae were observed only at Njoro. In contrast, Polycentropodidae were encountered at the Canners-Up and-Downstream sites and at Bora Milk only. *Hydropsyche sp*. was present at all sites almost always among thick moss plants growing on rocks. Among the Hemiptera, *Notonecta sp*. and *Corixa sp.* were encountered only at Confluence. Among the Coleoptera, Elmidae and Hydroscaphidae did not discriminate sites based on the location of point sources. The Odonata, Libellulidae and Coenagrionidae were observed only at Kenyatta thereby indicating their affinity for warmer but less polluted water.

Among the Diptera, Dixidae and Arthericidae occurred at the Egerton University site only. Tabanidae occurred at Bora Milk only while Dolichopodidae and Sciomyzidae were recorded at Bora Milk and Njoro. Simulidae and Ceratopogonidae did not discriminate sites on the basis of point source locations. In contrast, Tipulidae was encounterd only at Confluence, thus indicating its intolerance to effluent pollutants. Among the Chironomids, Tanypodinae type I occurred at all sites but almost always more abundant at the upstream cleaner sites. Type II occurred only at Egerton University, Canners Upstream and Bora Milk which indicates its affinity for polluted sites. Chironomini and Orthoclanidinae occurred at almost all sites but were always more at Egerton University, Canners Downstream and Bora Milk especially during the wet season.

Table 1: Summary of physico-chemical parameters measured in Njoro River both over the dry and wet seasons for the study period. Note that the blank part of the table corresponding to the wet season at Canners Upstream (site 6) was caused by inaccessibility of the site due to high river levels and the slippery nature of the site.

Site	Season	pH		TOC		Ammonium-N		Nitrate -N		Organic N		PH4 -P		Total P	
		Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1	Dry	7.9	0.09	31.78	34.37	0.2	0.92	0.1	0.11	0.3	0.62	0.1	0.11	0.25	0.1
1	Wet	7.3	0.12	47.81	34.37	0.2	0.92	0.2	0.11	0.7	0.62	0.1	0.11	0.19	0.1
2	Dry	7.4	0.09	40.73	34.37	0.3	0.92	0.1	0.11	0.8	0.62	0.1	0.11	0.33	0.1
2	Wet	7.6	0.12	38.6	48.6	0.0	1.29	0.2	0.15	0.4	0.87	0.1	0.15	0.27	0.2
3	Dry	7.3	0.09	13.05	48.6	0.4	1.29	0.2	0.15	0.7	0.87	0.1	0.15	0.27	0.2
3	Wet	7.6	0.12	18.27	48.6	0.0	1.29	0.2	0.15	0.4	0.87	0.1	0.15	0.26	0.2
4	Dry	7.4	0.09	23.91	34.37	0.6	0.92	0.2	0.11	1.6	0.62	0.3	0.11	0.31	0.1
4	Wet	7.6	0.12	27.1	48.6	0.1	1.29	0.2	0.15	0.1	0.87	0.1	0.15	0.37	0.2
5	Dry	7.7	0.09	14.97	34.37	0.7	0.92	0.2	0.11	0.9	0.62	0.3	0.11	0.51	0.1
5	Wet	7.5	0.12	22.9	48.6	0.1	1.29	0.2	0.15	0.5	0.87	0.3	0.15	0.13	0.2
6	Dry	7.8	0.09	49.86	34.37	0.6	0.92	0.2	0.11	1.7	0.62	0.3	0.11	0.19	0.1
6	Wet														
7	Dry	7.4	0.09	53.35	34.37	3.1	0.92	0.4	0.11	4.4	0.62	0.3	0.11	0.51	0.1
7	Wet	7.7	0.12	36.41	48.6	0.1	1.29	0.2	0.15	0.5	0.87	0.1	0.15	0.29	0.2
8	Dry	7.7	0.09	128.45	34.37	0.4	0.92	0.1	0.11	1.1	0.62	0.3	0.11	0.37	0.1
8	Wet	7.5	0.12	172	48.6	0.1	1.29	0.2	0.15	0.3	0.87	0.1	0.15	0.26	0.2
9	Dry	7.6	0.09	20.73	34.37	0.4	0.92	0.1	0.11	0.8	0.62	0.2	0.11	0.25	0.1
9	Wet	7.5	0.12	52.2	48.6	0.6	1.29	0.1	0.15	0.6	0.87	0.3	0.15	0.18	0.2
10	Dry	7.6	0.09	95.07	34.37	0.5	0.92	0.2	0.11	1.3	0.62	0.2	0.11	0.39	0.1
10	Wet	7.3	0.12	36.8	48.6	0.1	1.29	0.2	0.15	0.3	0.87	0.1	0.15	0.27	0.2

Table 2 : Summary of composition and community structure of benthic macro invertebrates from the middle reaches of Njoro River

SITE		COMPOSITION					SEASONAL STRUCTURE							
							Richness				Diversity			
		Diptera	Tricho-ptera	Ephe-merop tera	Coleo ptera	Other	Dry		Wet		Dry		Wet	
							µ	± SE	µ	± SE	µ	± SE	µ	± SE
1	Confluence	8	5	4	3	9	12.9	4.95	8.8	4.95	0.76	0.08	0.67	0.08
4	Egerton	10	1	3	8	8	13.2	5.42	3.44	7	0.69	0.08	0.48	0.11
5	Canners-Up	6	2	3	3	6	12.3	4.95	5.26	7	0.83	0.08	0.57	0.11
6	Canners-Down	9	1	2	2	9	8.9	5.42			0.68	0.08		0.11
7	Bora	9	3	3	2	8	9	4.95	5.7	7	0.76	0.08	0.55	0.11
8	Njoro	8	4	3	3	10	28.6	4.95	9.8	7	0.84	0.08	0.8	0.11
9	Kenyatta	6	1	3	4	5	6.9	4.95	7.2	7	0.6	0.08	0.44	0.11

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