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RESEARCH ARTICLE

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Macroinvertebrate Drift as an Indicator of Disturbance in a Kenyan Highland Stream: The Njoro River

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Abstract

Many Kenyan streams are influenced by humans through disturbances such as water *abstraction, farming and grazing in the riparian areas. However, there is limited information on the effect of natural and anthropogenic disturbances on drift, an important ecological process in streams. An investigation to assess the effect of disturbance on invertebrate drift was carried out between December 2015 and July 2016 in the Njoro River, Kenya. Three study sites differing in intensity of observable human and livestock activities were designated for study and included Mugo, Mary Joy and Turkana. The study involved sampling macroinvertebrates in drift and benthos at different study sites, during periods characterized by low and high-water discharge and during different times (i.e., night, day). Results showed that three taxa: Ephemeroptera, Chironomidae and Simuliidae, dominated drift samples at all sites. The study site (i.e., Turkana) with the lowest benthic invertebrate densities had the highest relative invertebrate drift densities (41-70%) during the high discharge period while the study site (i.e., Mugo) with the highest benthic densities portrayed relatively low (6-11%) invertebrate drift densities during the same period. Higher invertebrates drift density was recorded during the night than during the day. Study site location, discharge and time of sampling did not have a significant effect on invertebrates drift density. However, sampler location (i.e., DR1 – in drift and DR2 – out drift) had a significant effect (p=0.0004) on invertebrate drift density in the Njoro River. In conclusion, study site characteristics (e.g., topography - pool or riffle, and disturbance), hydrological regime and time of sampling are important factors to consider when evaluating invertebrate drift in streams. Future studies should consider evaluating the effect of other factors, such as water quality, mining and damming, on invertebrate drift in streams. Water resource managers should put into place measures to prevent further degradation along the river to protect in-stream macroinvertebrate habitats.*

Keywords: Benthos, Discharge, Anthropogenic, Lotic Ecosystem, Tropical

INTRODUCTION

Macroinvertebrate drift refers to the downstream movement of organisms in the water current (Brittain & Eikeland, 1988). Drift is an ecologically important phenomenon in running water ecosystems which plays a crucial role in distribution of organisms and in recolonization of river reaches after disturbance events (e.g. floods). Drift is a way for organisms to evade predators and is a source of nutrition for fishes which feed on drifting insects (Mathooko, 2000; Naman *et al.*, 2016). Moreover, the composition of invertebrates in drift in running waters usually reflects the invertebrates in the benthic zone and evaluation of invertebrate drift is a crucial means of assessing the distribution and composition of benthic invertebrates (Ramirez & Pringle, 2001).

Drift is done voluntarily (active) or involuntarily (passive) by invertebrates at any stage in their life cycle (Brittain & Eikeland 1988). This phenomenon has been studied widely in temperate streams (Kennedy *et al*., 2014) and to a lesser extent in tropical streams (Mureithi *et al*., 2018). Of interest is the observation that macroinvertebrates drift in large numbers during the night than during the day, most likely as an adaptation to avoid visually hunting predators (Flecker, 1992; Foresster, 1994; Ramírez & Pringle 1998). Other causes of macroinvertebrate drift are changes in abiotic factors such as discharge (Gibbins *et al*., 2005), siltation (Gomi *et al*., 2010) and light intensity (Henn *et al*., 2014). Anthropogenic disturbances also affect macroinvertebrate drift in streams (Lauridsen & Friberg, 2005; M'Erimba *et al*., 2018).

Besides the aforementioned factors, macroinvertebrate drift has been observed to fluctuate with season in some tropical rivers (Castro *et al*., 2013). However, sometimes clear seasonal patterns are not discernible, suggesting that benthic communities are subject to similar stresses throughout the year, and that populations grow and reproduce continuously (Ramírez & Pringle, 1998; 2001). Drifting macroinvertebrates are derived from the benthic zone and spend very little time in the water column (Elliott, 2002; 2003). Insects (mainly mayflies and dipterans) dominate drift samples while non-insects are rarely found in drift samples (Danehy *et al*., 2011).

Human-related disturbances in the riparian zones of running water ecosystems affect the connection between terrestrial and aquatic zones (Naiman & Decamps 1997). For example, deforestation in riparian zones affects the adjacent stream ecosystems by increasing sediment load, modifying river flow conditions, increasing river access and physical perturbations (e.g. trampling) by humans and domestic animals and modification of primary and secondary production (Hartman *et al*., 1996; Stone & Wallace, 1998). Subsequently, modification of these factors influences macroinvertebrate drift dynamics in rivers.

The Njoro River experiences small-scale anthropogenic disturbances, on daily basis, such as water abstraction, washing of clothes, watering of livestock, bathing and swimming. These activities are strongly dependent on the time of the day and season. Mathooko, 2001, shows that the intensity of anthropogenic activities was highest around midday during the dry season, a period characterized by low discharge and high demand for water. On the other hand, the author found that anthropogenic disturbances were less intense during the period characterized by high discharge, presumably due to reduced demand for river water due to increased availability of water from roof catchments. The Njoro River in Kenya has been extensively studied with respect to the effect of human-induced disturbances on benthic communities and water quality (Mathooko & Kariuki, 2000; Mathooko, 2001; M'Erimba *et al*. 2006; 2014; 2018; M'Erimba & Chepkorir, 2019). However, the effect of these disturbances on macroinvertebrate drift has rarely been studied. This study aimed to address the question whether disturbances (natural and anthropogenic) have any significant effect on macroinvertebrate drift in the Njoro River. The study predicted that macroinvertebrates would respond to disturbances by drifting downstream, and that macroinvertebrate drift densities would differ among study sites differing in intensity of disturbances. Further it was predicted that macroinvertebrate drift densities would differ between in-drift and out-drift samplers and between different sampling times (day, night).

MATERIALS AND METHODS

Description of Study Area and Sites

Njoro River is a second order stream draining a catchment of approximately 250 km^2 (Osano, 2015). It straddles between latitude 0° 15´S, 0° 25´S and longitude 35° 50´E, 36°

5´E (Figure 1). The origin of this river is Olokurto Division, Entiyani Location, at an altitude of about 2887 m in the Eastern Mau, Narok County. The river discharges into Lake Nakuru, at an altitude of about 1750 m having covered a distance of 55 km after traversing through Logoman forest, farm lands and densely populated commercial centres. The soils in the catchment area are predominantly volcanic-clay-loam (Baldgya *et al*., 2007). Generally, rainfall patterns in the Njoro area show a characteristic bimodal distribution, with much of the rain falling in April and August, but rain can fall at any time of the year. The river is permanently flowing at the upper reaches, becomes intermittent towards the lower reaches and ceases to flow during extreme droughts (Mathooko *et al*. 2005). Montane *Juniperus procera*-*Olea europaea* spp. *africana* and submontane *Acacia abyssinica* forests were the main riparian vegetation plants along this river (Mathooko & Kariuki, 2000), but the riparian vegetation has been greatly modified by man over time (Baldgya *et al*., 2007).

Three study sites (Figure 1) were chosen along the Njoro River based on the intensity (low, moderate, high) of anthropogenic disturbances. The first two sites were approximately 200 m away from each other while the third site (Tukana) was approximately 500 m away from the second site. They were coded as Mugo-LDS (least disturbed site), Mary Joy-MDS (moderately disturbed site) and Turkana-HDS (highly disturbed site).

Mugo site was heavily shaded by riparian trees and canopy cover intensity was about 80%, with a well-developed herbaceous layer on both banks. There was a small-scale farm that extended 50 m from the right river bank. The right river bank was occupied by the surrounding community while the left river bank bordered Egerton University, was well vegetated and had minimal physical anthropogenic disturbances. The site was categorized as the least disturbed site.

The second site, Mary Joy, bordered a human settlement on the right bank and Egerton University on the left bank. This study site had trees and a well-developed herbaceous layer on the left bank, but the right bank was devoid of vegetation, except for patches of Kikuyu grass (*Pennisetum clandestium*). Canopy cover intensity was 30% and was largely contributed by a single *Syzygium cordatum* tree on the left bank. The main anthropogenic disturbances observed during the current study, and by another recent study (M'Erimba & Chepkorir, 2019), included washing of clothes, bathing and water abstraction. Turkana was the third study site and bordered Egerton University staff residential buildings on the left river bank. The site had a narrow strip of vegetation that provided < 5% canopy cover. The main anthropogenic activities at this site included livestock watering, water abstraction, car washing, bathing and laundry (Mathooko, 2001). Effects of anthropogenic activities on water quality in the Njoro River have been documented elsewhere (Yillia *et al.*, 2008 a, b). Details of the study sites geographical positions and physico-chemical characteristics are provided in Table 1.

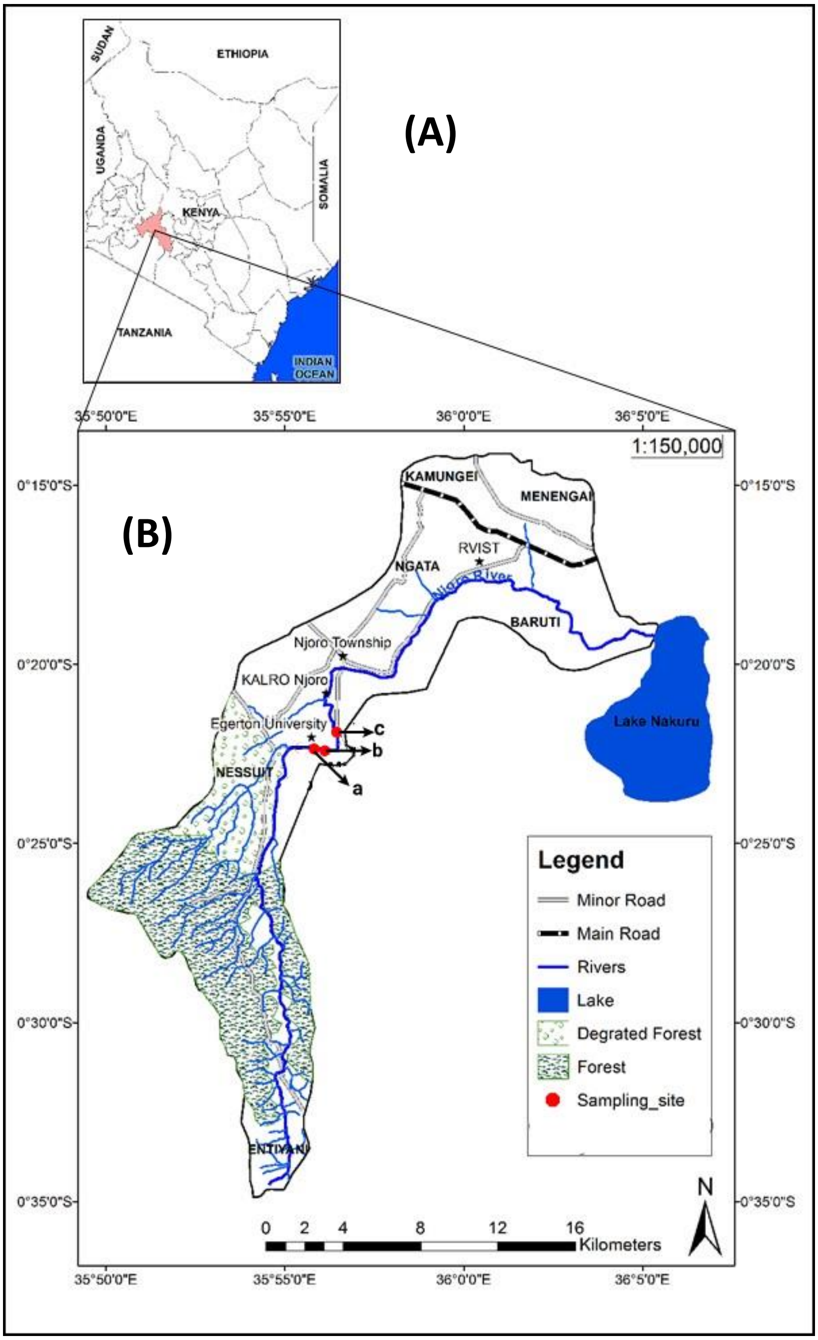

Figure 1: Location of the Njoro River in Kenya (A), the Njoro River from the Source to the mouth (B). Study Sites (a = Mugo, b = Mary Joy, c = Turkana).

Sampling Design

Sampling was carried out after every two weeks between December 2015 and July 2016 to cover the periods of low discharge (December 2015 - February 2016) and high discharge (May 2016 - July 2016), respectively. Drift samples were collected at four intervals of 2 hrs each during day time and night time. The first two intervals were done during the day between 0600-0800 and 1100-1300, when human and animal water interactions are at peak, and between 1800-2000 and 2200-2400 during the night, when anthropogenic activities are presumed to be absent (Mathooko, 2001). Sampling times were also planned to coincide with drift peak hours observed from a separate study done in 2012 at the same river by M'Erimba *et al*., (2017). Ten benthic macroinvertebrate samples were randomly collected after drift sampling, during the day, for purposes of determination of the proportion of benthic macroinvertebrates in drift. Benthic macroinvertebrates were collected using a modified Hess sampler (area = $0.029 m^2$) across the river reach.

Table 1: Physical and chemical variables (given in ranges and means) measured during the study period at the three study sites. LDS, MDS, HDS refer to Least Disturbed, Moderately Disturbed and Highly Disturbed Sites. SE = Standard Error

	Sites		
	Mugo (LDS)	**Mary Joy (MDS)**	**Turkana (HDS)**
Latitude	00°22′ 32.05S	00°22′ 31.05S	00°22′ 22.45S
Longitude	35°56′ 17.65E	35°56′ 03.85E	35°56′ 31.85E
Elevation (m.a.s.l)	2255	2271	2245
Length (m)	65	84	80
Width (m)	5.5	5.9	7.3
Average water depth (m)	0.52	0.64	0.75
Slope range	23.3° - 36.5°	16° - 35°	21° - 27°
Canopy cover (%)	80	30	<5
Dominant biotope	Sand and mud	Boulders and rocks	Shallow bedrock
Temperature (°C)	12.4 – 15.3	12.3 – 14.9	12.8 – 16.0
Conductivity ($\mu S\ cm^{-1}$)	117.7 – 143.1	119.8 – 139.8	112.6 – 163.1
Dissolved Oxygen ($mg\ l^{-1}$)	8.4 – 10.7	9.0 – 9.1	8.6 – 11.3
pH	6.2 – 7.0	6.2 – 6.9	6.1 – 7.0
Velocity (ms^{-1})	0.17 – 0.19	0.14 – 0.17	0.12 – 0.24
Low discharge (m^3s^{-1}) (± SE)	0.12 ± 0.03	0.30 ± 0.15	0.35 ± 0.17
High discharge (m^3s^{-1}) (± SE)	1.54 ± 0.63	1.06 ± 0.43	3.30 ± 1.35

Physico-Chemical Parameters

Physico-chemical parameters were determined by taking three *in situ* readings at each sampling site during each of the 15 sampling occasions. Conductivity was measured at every site with a WTW-LF 90 conductivity meter. Dissolved oxygen and percentage oxygen saturation were determined using a WTW-OX 192 oxygen meter while pH and water temperature were determined using a combined WTW - pH 91 meters. Discharge was computed as described by Gordon *et al*. (1993) whereas water velocity was determined at 60% of the total water depth with a General Oceanic flow meter (model 2030R) at each site.

Drift Sampling and Sample Processing

To determine the effect of physical anthropogenic disturbance on macroinvertebrates, two drift samplers (mesh-size: 100 µm) were used and were coded as DR1 and DR2, respectively. The DR1 sampler measured invertebrates drifting into a site while DR 2 sampler measured invertebrates drifting out of a site. The assumption is that macroinvertebrates drifting into a disturbed site would opt to drift further downstream than enter into the sediments (Bretschko, 1990). Detailed information of the drift samplers used in this study have been provided by Wagner (2000). For each sampling event, DR1 was placed upstream of the study site, to quantify in-drift (natural drift not affected by disturbance), while DR2 was placed downstream of the study site, to quantify out-drift (drift under the influence of disturbance), respectively. The distance between the two drift samplers varied depending on the site conditions and the level of water, but was always maintained between 30 – 50 m since macroinvertebrates are known to drift over very short distances (Elliot, 2002).

During sampling, the two drift nets were exposed for 15 mins, emptied into sample bottles to avoid net clogging and re-set on five consecutive occasions, resulting in 20 samples per sampler per day. In total, 40 drift samples were collected at each site per sampling occasion. This resulted in 600 drift samples by the end of the study. On the other hand, a total of 180 benthic samples were collected by the end of the study. The samples were well labelled, fixed with 5% formalin and taken to the laboratory for further processing. In the laboratory, the collected samples were washed into a series of sieves to remove formalin and the macroinvertebrates sorted by hand and preserved in 70% alcohol. Identification was done to the lowest level possible with the aid of a stereomicroscope and the identification keys by Gerber & Gabriel (2002). Drift densities (individuals per m^3) were determined as explained by Ramírez & Pringle (1998) by dividing the number of invertebrates in a sample by the volume of water sampled (through flow). The percentage (P %) of the benthos in drift was calculated by applying the formula provided by Shearer *et al.* (2003) as follows: $P = (xD.100) / (X + xD)$, where x = drift density (indiv. per m^3), D is the average depth in metres (m), and X = the mean benthos density (indiv. per m^3).

Data Analysis

The effect of study site location (Site), season (low and high discharge), time of day (day, night) and sampler (DR1, DR2) on invertebrate drift density was evaluated using Linear Mixed-Effect Models (LMM), with study site location, season, time of day and sampler being fixed factors. Study site location, sampler, time of day and season were included as interaction terms. Pairwise comparisons for statistically significant models were made using Tukey contrasts (Hothorn *et al.*, 2008). Model residuals were evaluated for normality and homoscedasticity following Zuur *et al.* (2009). The Holm's correction (Holm 1979) method was applied to adjust *p*-values for multiple testing and the corrected *p*-values are reported. Data analysis was performed using the R statistical package (R Development Core Team 2018).

RESULTS

Insects dominated invertebrate drift samples in the Njoro River, forming more than 94% of the total invertebrates abundance. The main insect orders were Ephemeroptera (Baetidae and Caenidae) (40%), Chironomidae (51%) and Simuliidae (4%). Although oligochaetes were commonly found in the benthic samples (2-88% of total invertebrates abundance), they were rarely found in drift samples (<1% of total invertebrates abundance). Other insects (e.g., Hydropsychidae, Ceratopogonidae, Coleoptera) and non-insects (e.g., Hydrachnellae, nematodes and Hirudinea) drifted in very low numbers (<5% of total invertebrates abundance). Invertebrate taxa richness was higher in benthic (18) than in drift (11) samples.

The relative abundance of the major invertebrate groups that drifted at the Turkana study site was highest (41-70%) during the season with high discharge compared to the season with low discharge (16-32%) (Table 2). The relative abundance of invertebrates that drifted at Turkana site exceeded those in benthic samples. On the other hand, the relative abundance of the major invertebrate groups that drifted at the Mugo study site was highest (35-58%) during the low discharge period, compared to the period characterized by high discharge (6-11%) (Table 2).

Table 2: Major macroinvertebrate taxa (Abundance and % of total abundance) sampled from benthos and drift at the Njoro River study sites. L and H refer to seasons with low and high discharge, respectively

	Ephemeroptera				Chironomidae				Simuliidae			Total invertebrates abundance			
	Benthos	%	Drift	%	Benthos	%	Drift	%	Benthos	Drift	%	Benthos	%	Drift	%
Mugo															
(L)	5068.9	96	1767.9	35	27965.5	83	5268.5	58	0	202.6	44	58206.9	47	7239	50
(H)	8448.3	76	292.3	6	10310.3	72	285.9	9	34.5	78.1	11	116620.7	86	656.3	7
MaryJoy (L)															
(H)	137.9	3	1604.7	32	4620.7	14	2359.7	26	2413.8	153.1	33	62241.4	50	4117.5	28
	1965.5	18	1202.8	24	2206.9	15	861.7	28	0	331.7	48	11206.9	8	2396.	27
Turkana (L)															
(H)	68.9	1	1609.9	32	1310.3	4	1418.5	16	0	106.0	23	3103.5	3	3134.5	22
	655.2	6	3530.3	70	1827.6	13	1906.8	62	34.5	286.2	41	8310.3	6	5723.3	65

Additionally, the relative abundance of the major invertebrate groups in benthic samples at the Mugo study site was higher (83-96%) during the low discharge period than during the high discharge period (50-76%). Discharge did not have a significant effect ($p = 0.8$) on invertebrate drift abundance in the Njoro River. However, the Site x Discharge interaction term was statistically significant ($p = 0.01$) (Table 3). Time of sampling did not have a significant effect ($p = 0.3$) on invertebrate drift abundance (Table 3). However, when samplers were considered, it was observed that sampler DR1 collected significantly higher invertebrates abundance than sampler DR2 (Table 3). The Sampler x Discharge interaction term also had a significant effect ($p = 0.01$) on invertebrates drift abundance.

When data was pooled together, the highest (65%) relative invertebrate drift abundance was recorded at the Turkana study site during the high discharge period while the lowest (7%) invertebrate drift abundance was recorded at the Mugo study site during the same time period (Table 2). However, Site did not have a significant effect on invertebrate drift abundance in the Njoro River (Table 3).

Table 3: *F*-ratio and *p*-values for the Mixed-Effects Models evaluating the effects of study site location, time (Day, Night), sampler (DR1, DR2) and discharge (Low, High) on invertebrate drift abundance in the Njoro River. Significant values ($p<0.05$) are highlighted in bold. df = degrees of freedom

Effect	df	*F*-ratio	*p*-value
Site	2	2.5	0.2
Time	1	1.2	0.3
Sampler	1	23.4	**0.0004**
Discharge	1	0.05	0.8
Site x Time	2	1.9	0.2
Time x Sampler	1	0.7	0.4
Site x Discharge	2	4.6	**0.01**
Time x Discharge	1	0.4	0.5
Sampler x Discharge	1	9.8	**0.001**
Site x Time x Sampler	2	0.7	0.5
Site x Time x Discharge	2	0.09	0.9
Site x Sampler x Discharge	2	0.2	0.8
Time x Sampler x Discharge	1	0.2	0.6

With regard to invertebrates in benthic samples, Mugo study site had the highest mean abundance of invertebrates in benthos while Turkana study site had the lowest mean abundance of invertebrates in benthic samples (Figure 2). The highest % proportion of benthos in drift was recorded at the Turkana study site during the high discharge period while Mugo study site had the lowest % proportion of benthos in drift during the same time period (Figure 2). During low discharge, the highest % proportion of benthos in drift was also recorded at the Turkana study site while the lowest % proportion of benthos in drift was recorded at the Mugo study site (Figure 2).

During low discharge, mean invertebrate drift abundances during the day and night time periods were 24 ± 1.4 individuals m^{-3} and 33.4 ± 2.5 individuals m^{-3}, respectively. During high discharge, the mean invertebrate drift abundances were 27.9 ± 6.5 individuals m^{-3} for day time and 29.1 ± 5.7 individuals m^{-3} for night time. During low discharge, generally high invertebrate drift abundances were recorded during night time, compared to the high discharge period when the day and night invertebrate drift pattern was not clear (Figure 3).

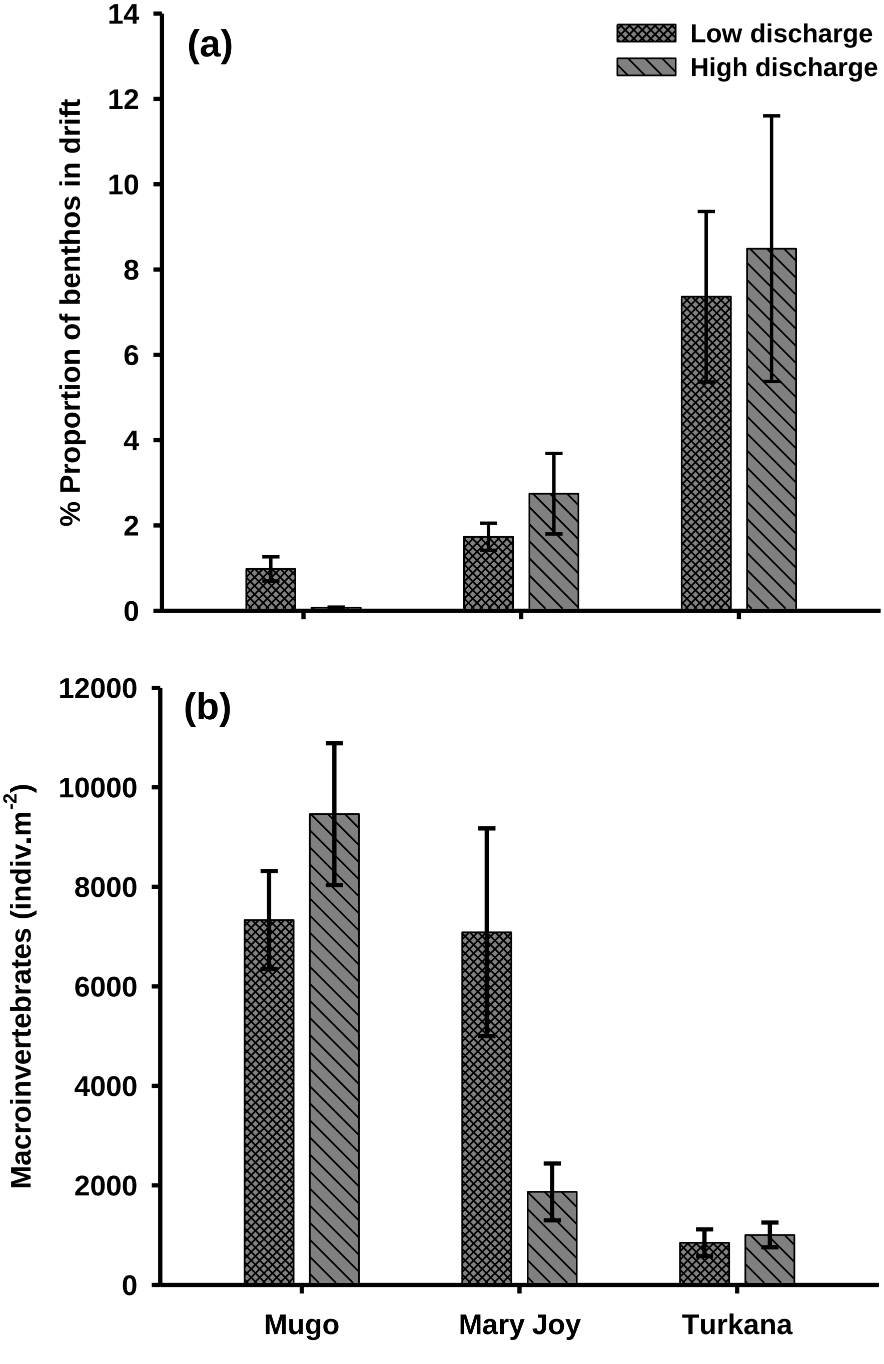

Figure 2: Proportion of benthos in drift (a) and benthic densities (b) collected at each site during both discharge periods.

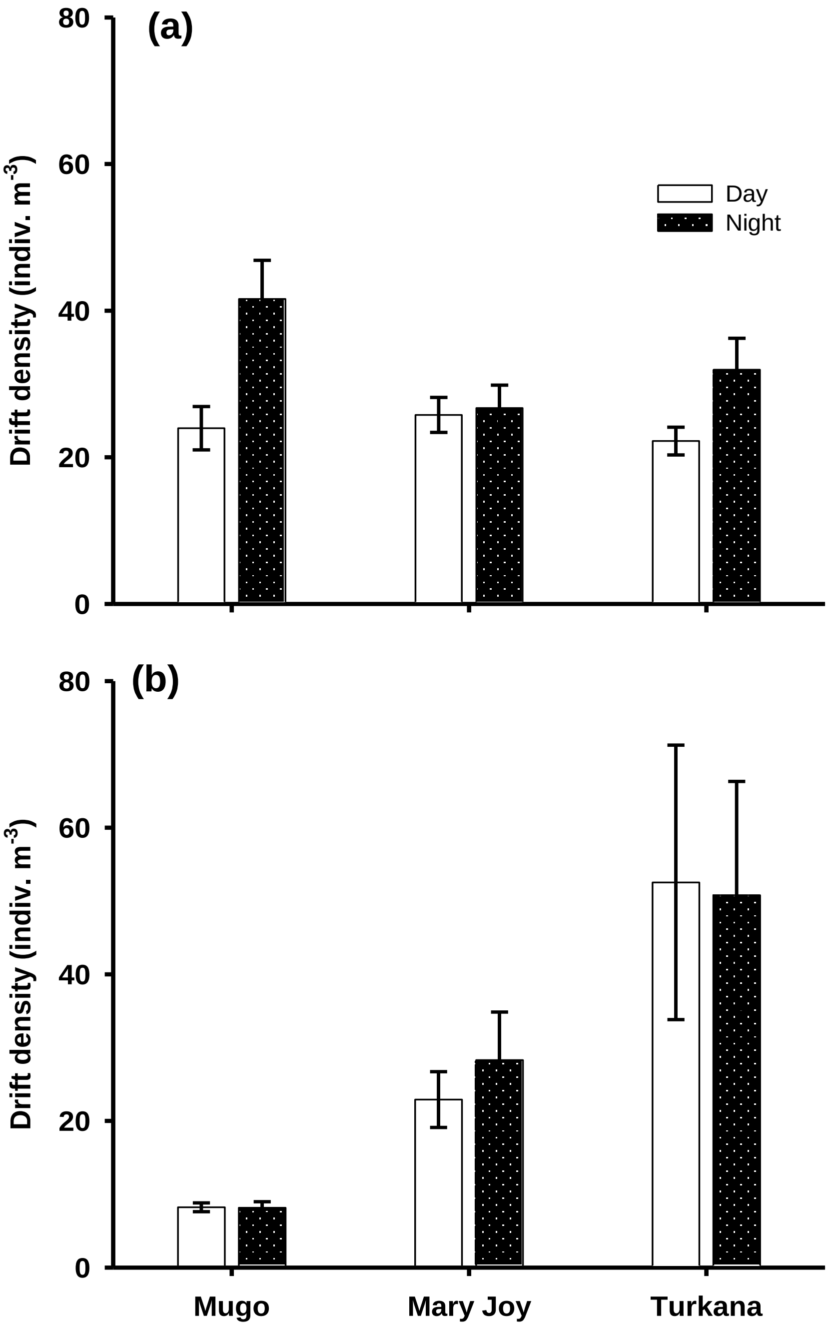

Figure 3: Day and night time invertebrate drift densities during Low (a) and High (b) discharge periods in the Njoro River.

DISCUSSION

Application of macroinvertebrates in monitoring the effects of human disturbances on stream ecosystem requires proper understanding of their ecology. Metrics such as abundance, taxon richness, diversity, percentage Ephemeroptera, Plecoptera, Trichoptera (%EPT) and those which reflect response to ecosystem functions are commonly used (e.g. functional feeding groups) (Masese *et al*., 2013). Invertebrate drift is a response by macroinvertebrates to either natural cues (Gibbins *et al*., 2005), or human influences (Lauridsen & Friberg 2005). The observation that invertebrates respond quickly by entering into drift in large numbers in the face of human perturbations (Bretschko, 1990; Mori & Brancelj, 2011) and on application of pesticides (Beyers *et al*., 1995) indicates that drift is an important indicator of disturbance in aquatic ecosystems. Just as reported in other studies like Mureithi *et al*. (2018), insects dominated drift in this study and more invertebrates were found to be drifting during the night than during the day. A similar observation was reported in earlier studies by Bass (2004) and Thornton (2008). Light is known to suppress invertebrate drift in running waters (Henn *et al*., 2014) and invertebrates take cover within microhabitats in the streambed to avoid visually oriented predators (Flecker, 1992; Ramírez & Pringle, 1998).

The observation that drift densities were higher during the night than during the day in this study differs from another study conducted in the same river by M'Erimba *et al*. (2018). The authors reported that invertebrate drift densities were highest during the day than during the night and attributed this result to physical anthropogenic disturbances in the Njoro River site during day time hours. The possible explanation for the differences in drift densities between studies is that different types of anthropogenic disturbances affect Njoro River and they could be influencing invertebrate drift differently. For example, in the study by M'Erimba *et al*. (2018), he evaluated invertebrates at a single site which was affected by physical anthropogenic disturbances such as livestock trampling. On the other hand, in the current study, some of the study sites (e.g. Mugo) were not much affected by in-stream physical disturbances which could increase invertebrate drift densities. Other factors such as position of drift sampler and stream bed topography can also influence invertebrate drift densities in streams (Mureithi *et al.,* 2018).

Discharge influences drift densities in streams. Gibbins *et al*. (2010) observed that three different families of mayflies (Baitidae, Caenidae and Heptageniidae) responded differently to increased sheer stress and river-bed instability. The authors noted that sheer stress was more important to cause drift in Baetidae and Heptageniidae than bed disturbance, as opposed to Caenidae where the two variables were equally important. Naman *et al.* (2016) in their review on causes and consequences of invertebrate drift in running waters pointed out that predisposition to drift will vary among taxa depending on behavioral, ecological, and morphological traits. In this study, mayflies and diptera were common in drift and appeared to be influenced by both discharge and anthropogenic disturbances. Ephemeroptera and Chironomidae, for instance, decreased from the least disturbed site to the highly disturbed site in the benthos and were affected differently in terms of drift. Kennedy *et al.* (2014) observed that Chironomidae increased while Simuliidae, which are associated with high-velocity cobble microhabitats, decreased by over 80% as discharge doubled in Colorado River. The authors concluded that invertebrate drift concentrations in this river are jointly controlled by discharge and benthic densities, but these controls operate at different time scales. The observation that oligochaetes were numerous in benthos and rare in drift samples supports the argument that the effect of anthropogenic disturbances and discharge affects invertebrates differently.

The observation that more macroinvertebrates drifted at Turkana site in respect to their numeric proportions in the benthos, unlike at the Mugo and Mary Joy sites, could be most likely attributed to anthropogenic disturbances that are more intense at this site. Constant trampling on the stream channel by vehicles, humans and livestock could lead to sediment compaction and water quality deterioration, and thus high macroinvertebrate drift densities (Bretschko & Klemens, 1986). Sediment compaction in itself could limit the mobility of benthos in the sediments during disturbances, thus opting to drift. Furthermore, Mathooko (1999) in his manipulation experiments in a relatively undisturbed Kenyan highland stream observed that sediments that were frequently disturbed and those that were undisturbed had the least number of mayfly abundance and diversity, unlike those that experienced moderate disturbances. Bretschko & Klemens (1986) in their sediment coring experiments in a calcareous mountain stream in Austria observed that macroinvertebrates escaped disturbances by entering into drift. Similarly, Mori & Brancelj (2011) observed an increase in benthos in drift during gravel excavation in river Bača, a 4th order stream in the Western part of Slovenia. The low benthic densities observed at disturbed sites in this study could also be attributed to sediment clogging on these sites. Bossley & Smiley (2019) observed that constant sediment trampling in a fourth order stream in central Ohio resulted in reduction in macroinvertebrate abundance and richness. Fine silt embedded the shallow bedrocks at Turkana and Mary Joy sites. Increase in siltation as a result of anthropogenic sediment trampling increases sediment homogeneity, reducing abundance and diversity of macroinvertebrates. Bo *et al*. (2007) observed that clogging and accumulation of fine substratum elements caused a reduction in the number of taxa and abundance in Lemme creek in North West Italy. A similar observation in reduction of species and abundance was also reported by De Castro Vasconcelos & Melo (2008) after adding fine and coarse sediments to a stream section. Another study by Mbaka *et al*. (2014) evaluated the effect of habitat quality on benthic macroinvertebrates in the Honi and Naro Moru Rivers, Kenya, and found that study sites with high fine sediment content had lower macroinvertebrate abundance and taxa richness.

Disturbances, though occurring on a small-scale, but on daily basis, in the Njoro River might cause sediment compaction and loss of refugia for macroinvertebrates, especially during high water flow. This could explain the observed high drift densities during high discharge at the disturbed sites unlike at the Mugo site, which is the least disturbed site. At sites where disturbances are low or absent, drift densities are also low during high discharge (Gurtz & Wallace, 1984), most likely due to diversity of microhabitats that provide refuge for organisms during high water flow. During low water flow, however, high macroinvertebrate drift was observed at Mugo, the least disturbed site. This could be viewed as a survival strategy by the organisms whereby they drift in high numbers when water flow is low, a time when they can regulate drift distances and search for suitable habitats unlike during times of high discharge. According to Palmer (1992), drifting macroinvertebrates are derived from benthos and spend very little time in the water column. Bruno *et al*. (2016) demonstrated that upon disturbance of sediments, more than 90% of the drifting organisms had settled at only a distance of 10 meters downstream. Disturbances in the Njoro River most likely reduced substrate heterogeneity and caused loss of refugia, rendering the invertebrates prone to drift during high water flow as was evident at the Turkana site in the Njoro River. The observed increase in abundance of macroinvertebrates in the benthos at some sites during high discharge could be due to some insect species searching for refugia during high flows (Ríos-Touma *et al*., 2012).

The observation that DR1 (in-drift) collected significantly higher drift densities than DR2 (out-drift) at the moderately disturbed (Mary Joy) and highly disturbed (Turkana), irrespective of the time of the day, could probably arise as a result of differences in habitat type or drift patterns exhibited by individual organisms (Mathooko & Mavuti 1994). Constant disturbances at the sediment surface of the Njoro River resulted to formation of deep pools in the affected sites over time. Consequently, this could influence the densities of drifting invertebrates. Macroinvertebrates are known to concentrate in pools which act as traps or catching basins for stream drift (Dendy, 1944). Brooks *et al.* (2017) working in rivers draining Kosciuszko National Park in the Snowy Mountains region of south-east Australia established that drift dispersal between riffles was significantly hindered by the intervening pool habitat. Also, natural, large and slow-moving pools impede the number of invertebrates drifting between riffle habitats. Bailey (1966) and Waters (1966) demonstrated that the densities of invertebrates drifting from a riffle was greater than that drifting into it from a pool. They further demonstrated that fewer invertebrates drifted out of a pool than those that drifted into it.

High proportions of benthos that drifted were recorded at the highly disturbed site (i.e., Turkana) during both discharge regimes. Turkana was the highly disturbed site that was easily accessible by animals and humans that came to drink and fetch water on daily basis. The sediments here have been compacted over time due to these activities. This is thought to interfere with the downward mobility of macroinvertebrates, thus making them to drift. However, during the high discharge period, the proportion of benthos that drifted at the least disturbed site (i.e., Mugo) was lower when compared to the other sites. Least disturbed sites offer many micro-habits that act as refuge for macroinvertebrates during high discharge (Gurtz & Wallace, 1984). De Brouwer *et al*. (2019) demonstrated that refuge heterogeneity was important for lowland streams caddisfly larvae to escape from drift.

In the present study, the proportion of benthos that drifted in the Njoro River ranged between 0.43 – 6.99%. Scarsbrook & Townsend (1993) reported similar observations in New Zealand. The authors observed that the percentage proportion of benthos that drifted at the Timber Creek (disturbed) ranged from 0.009 – 0.03 %, whereas in the Kyeburn River the range was 0.003 – 0.012 %. Although most of the value range reported in literature is below 1%, values as high as 10% have been reported for streams in central Pennsylvania (Adler *et al*., 1983) and the values for Njoro River lie within this range.

CONCLUSION

In conclusion, disturbances affect invertebrate drift in streams and rivers. Study site characteristics, time of sampling (day, night), sampler location on stream bed and discharge are important factors to consider when studying invertebrate drift in streams. Future studies should focus on other factors like water quality, changes in vegetation cover, and epilithic sources of energy as some of the possible factors that could influence invertebrate drift in streams.

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