Variation of Human and Domestic Animal's Activities with Discharge in a High Altitude Tropical Stream, the Njoro River, Kenya

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Received	Reviewed	Accepted	Published
24th May, 2019	24th October, 2019	1st November, 2019	3rd December, 2019

Abstract

From ancient times human settlements and cultures thrived along river valleys which provided water for domestic use as well as agriculture. as population grew, human activities impacted river valleys as well as affected water quality. An investigation was carried out during low (January to March 2012) and high (August to October 2012) discharge regimes in the Njoro River to establish whether the river's discharge dictated the visit rate and activities by people and animals at three sites. The study involved counting of people and animals during the day between 1000 – 1300hrs that visited the river, and recording down the activities. The visit rate by people was statistically insignificant between low (30.75 ± 5.64 ind. hr^{-1}) and high (20.58 ± 3.41 ind. hr^{-1}) discharges respectively, (t = 1.544, d.f = 70, p > 0.05). A similar observation was made in mean visit rates by animals (t-value = 0.725, p > 0.05). However, significant differences in the rate of people and animals (pooled data) were evident among the sites during low and high discharge periods (one-way ANOVA, P < 0.001). More men fetched water at the most downstream site than women during both discharge regimes, and the opposite was evident at the first site. It is concluded that discharge did not influence significantly the visit rates and other factors that are site specific should be explored. Disturbances in the Njoro River are of press type and requires intervention for the management of this river.

Key words: Animals, Discharge, Disturbance, People, River, Sites, Visits.

Introduction

Inland waters are constantly under threat owing to disturbances by human and animals at various scales globally. Disturbances in aquatic bodies could occur either naturally or as a result of perturbations by humans and domestic animals. Natural disturbances include floods (Suren & Jowett, 2006), drought, (Acuña, *et al.,* 2005; Bond & Lake, 2005; Bond, *et al.,* 2008), natural fires, (Bisson, *et al.,* 2003; Smith *et al.,* 2011). Those induced by humans and animals vary from small scale to large scale and may include water abstractions (Mathooko, 2001; Matthaei, *et al.,* 2010), habitat destruction (Willson & Dorcas, 2003), vegetation removal (Mbaka, *et al.,* 2014), and Agriculture (Sarriquet, *et al.,* 2006; Gichana, *et al.,* 2014) among others. Lake (2000) categorized disturbances as "pulse" which are short term and sharply delineated for instance floods. "Press type" as disturbances that may arise sharply and then reach a constant level that is maintained. They include those induced by humans like channelization, damming and persistent pollution. "Ramps" are those disturbances that increase steadily in time without an end point, or reach an asymptote after an extended period e.g. droughts, increased sedimentation and so on.

Effects of disturbances in lotic systems depend on their duration, magnitude and severity. Pulse type disturbances could cause rearrangement of the benthic communities as a result of changes in physical and chemical characteristics (Lake, 2000). Press type and ramp are persistence and may cause a shift in benthos from more sensitive to more tolerant species including fish (Gage, *et al.,* 2004; Ferreira, *et al.,* 2007). Of interest to aquatic ecologists is how these disturbances shape ecosystems in question and how organisms respond. Pires, *et al.* (2000) observed that benthic macroinvertebrates recovered fast from severe droughts both in taxonomic diversity and in numbers in a Mediterranean stream in Portugal that was intermittent in nature. In another study Vasconcelos & Melo (2008) observed that short-term terrestrial sediment inputs impacted negatively on benthic macroinvertebrates in the Forqueta River, Brazil. However, sediment removal as a restoration management in fish ponds caused a reduction as well as a shift in taxonomic and functional composition in benthic macroinvertebrates in Štěpánek fishpond, Czech Republic (Sychra & Adámek, 2011).

In the Njoro River, small-scale anthropogenic disturbances occur on daily basis both during low discharge (dry season) and high discharge (wet season). They are thought to cause a reduction in benthic macroinvertebrates (M'Erimba, *et al.,* 2014) and quantities of organic matter both on the banks and in the streambed (M'Erimba, *et al.,* 2006). Mbaka, *et al.* (2014) observed that macroinvertebrates as well as organic matter were influenced by the extent of vegetation cover in three sites along the Njoro River. Open canopied sites were the most affected. Mathooko, (2001), working on a single site in this river observed that the activities were patterned and seasoned and became intense during dry season. Njoro River has been undergoing intense modifications by humans since 1994. The objective of this study was to characterize human and livestock activities in three sites within the middle reaches of this river, with a view of classifying sites as either less, moderate and highly disturbed. It was hypothesized that discharge regimes and closeness to residential areas influenced the type of activity, animals, categories and gender that visited the river.

Materials and Methods

Study River and Sites

Njoro River is a second order stream whose origin is traced at Olokurto Division, Entiyani Location, Entiyani Sub-location in Narok County (S00°34.588´; E035° 54.684´; altitude, 2887m.a.s. l). The catchment is about 250 squared kilometres in area and the river, with a length of 55 km, discharges into Lake Nakuru (Osano, 2015). Catchment population is over 600, 000 people (Lelo, *et al.,* 2005). Three sites (Fig. 1) were chosen within the middle reaches of this river based on their proximity to human settlements and accessibility namely; Mary Joy, Mugo and Turkana.

Mary Joy (00°22.54′ S, 35°56.12′ E; altitude, 2240 m a.s.l), measured 83 m in length, 5.9 m in width and a mean depth of 0.75 m. Canopy cover was 30% largely contributed by a single *Syzygium cordatum* tree on the left bank. Bank slopes ranged between 16° - 35° on the right and 22° - 24° on the left banks respectively. Sediments are soft and muddy with medians of 0.095 mm and much of organic matter from domestic animals. The sediments are poorly sorted; with sorting coefficients of 2.8 ± 0.20 SE, and percentage grain size less than 1mm of about 74%.

Mugo (00°22.57′ S, 35°56.27′ E; altitude, 2220 m a.s.l), measured 80 m in length, 5.5 m in width and a mean depth of 0.64 m. Vegetation was dominated by *Syzygium cordatum, Pittosporum viridiflorum, Pittosporum abyssinicum,* and *Maytenus senegalensis* among others providing 80% canopy cover. The slopes on both banks are 23.3° and 36.5°, respectively (Magana, 2000). Fine sediments predominate partly sandy and muddy (S_o = 2.66 ± 0.90), with grain size < 1mm forming 92% of the sediments sizes. Gravel substrates are scarce and rock boulders are evident at the river bottom.

Turkana site (00°22.39′ S, 35°56.53′ E; altitude, 2220 m a.s.l) and measured 65 m in length, 7.3 m in width and a mean depth of 0.52 m. The slopes are gentle with gradients ranging between 21° - 24° on the right bank, which borders an open grazing field. On the left bank, gradients ranged between 21° - 27°with scattered A*cacia spp.* trees that provided less than 5% canopy cover. Fine sediments that are poorly sorted (S_o = 2.8±0.20) predominate this site. The Physico-chemical characteristics of the study sites are presented in Table 1.

Table 1: Physico-chemical variables determined during the study period

	LOW DISCHARGE			**HIGH DISCHARGE**		
Stream variables	**Mugo**	**Mary joy**	**Turkana**	**Mugo**	**Mary joy**	**Turkana**
Temperature (°C)	**15.25**	**14.85**	**16.04**	**12.36**	**12.32**	**12.80**
± SE	0.34	0.28	0.33	0.81	0.83	0.84
Conductivity (µs cm^{-1})	**143.09**	**139.84**	**163.06**	**117.67**	**119.80**	**112.62**
± SE	7.99	9.54	5.59	7.89	7.58	7.57
Dissolved oxygen (mg l^{-1})	**10.69**	**9.00**	**11.33**	**8.36**	**9.09**	**8.55**
± SE	0.63	0.53	0.68	0.69	0.82	0.87
% Oxygen saturation	**125.96**	**103.96**	**136.04**	**85.05**	**85.68**	**102.76**
± SE	9.16	7.39	10.05	8.25	12.48	11.40
pH	**6.47-8.25**	**6.54-7.30**	**7.05-7.44**	**4.81-8.64**	**6.48-7.45**	**5.96-7.82**
Velocity (m s^{-1})	**0.17**	**0.14**	**0.12**	**0.19**	**0.17**	**0.24**
± SE	0.05	0.05	0.02	0.03	0.05	0.04
Discharge (m^3 s^{-1})	**0.12**	**0.31**	**0.40**	**2.71**	**1.40**	**3.46**
± SE	0.02	0.12	0.14	0.63	0.44	1.35
Canopy cover (%)	**80**	**30**	**5**	**80**	**30**	**5**

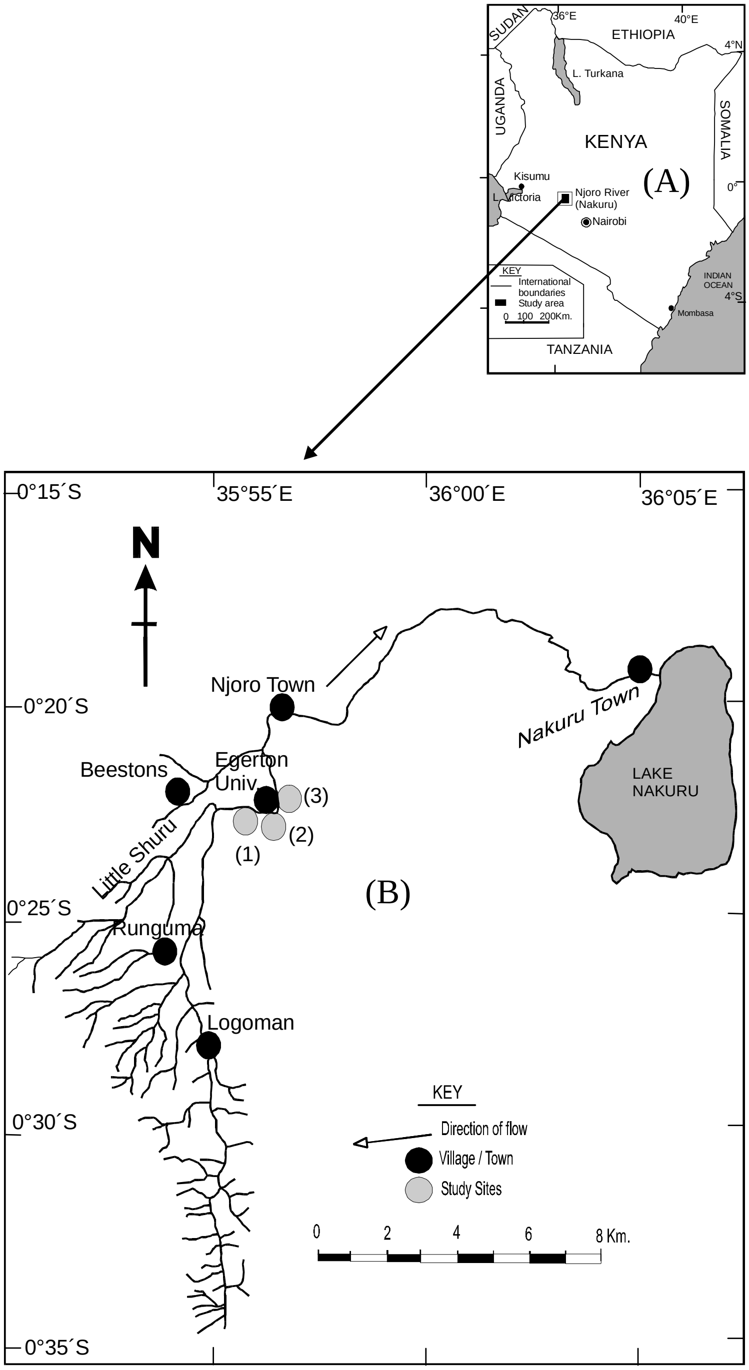

Figure 1: Map of Njoro River showing the study sites (a) location in Kenya and (b) the catchment

Census of People, Animals and Daily Activities

Counting of people, animals and activities was carried out during low discharge (January – March, 2012) and high discharge (November 2011, May to June, 2012). Low water flow (base flow) occurs during the dry season while high water flow occurs during the rainy season. A general pattern of activities was established by counting the number of people and animals at every site from dawn to dusk. The pick hours were established between 10.00 hrs - 1400 hrs. The people were categorized as men, women and children while animals were grouped as Cows, donkeys and sheep. The containers used for fetching water were classified as 20L or 100L (drums) respectively. Activities that were practiced at the three sites were noted and recorded during both discharge periods. The number of vehicles and bicycles that came for washing or ferrying water were also noted. Disturbances were later categorized as low, moderate or high per site.

Data Analysis

Since zero counts were encountered in some cases, the data was normalized by performing log (x+1) transformation. Visit rates were compared between the discharge periods using student t-test. Site specific differences in terms of activities as well as categories of people and animals were compared using One-way ANOVA. Two-way ANOVA was used to establish whether any significant interaction existed between the sites and discharge and the visit rates by animals as well people.

Results

The mean number of people (pooled data) that came to the stream during low discharge were 30.75 ± 5.64 individuals while during high discharge were 20.58 ± 3.41SE. These two means did not differ significantly ($t = 1.544$, d.f = 70, $p > 0.05$). A similar observation was made when animals were considered between low (14.94 ± 4.43 ind. hr^{-1}) and high (13.22 ± 4.42 ind. hr^{-1}) discharges respectively ($t = 0.275$, d.f = 70, $p > 0.05$). During low discharge, significantly more people visited the stream than animals ($t = 2.205$, d.f = 70, $p < 0.05$) while during high discharge the mean difference was statistically insignificant ($t = 1.319$, d.f = 70, $p > 0.05$). There occurred no significant interaction between discharge and sites in terms of visit rates by people (Two-Way ANOVA, $F_{(2,66)} = 0.032$, $p > 0.05$) and animals (Two-way ANOVA, $F_{(2,66)} = 0.533$, $p > 0.05$). Figure 2 depicts the visit rates per site by people and animals during low and high discharges. Very few people visited Mugo site while majority visited Mary Joy during both discharge periods (Fig. 2a). Turkana site was more frequented by animals than any of the other two sites (Fig. 2b).

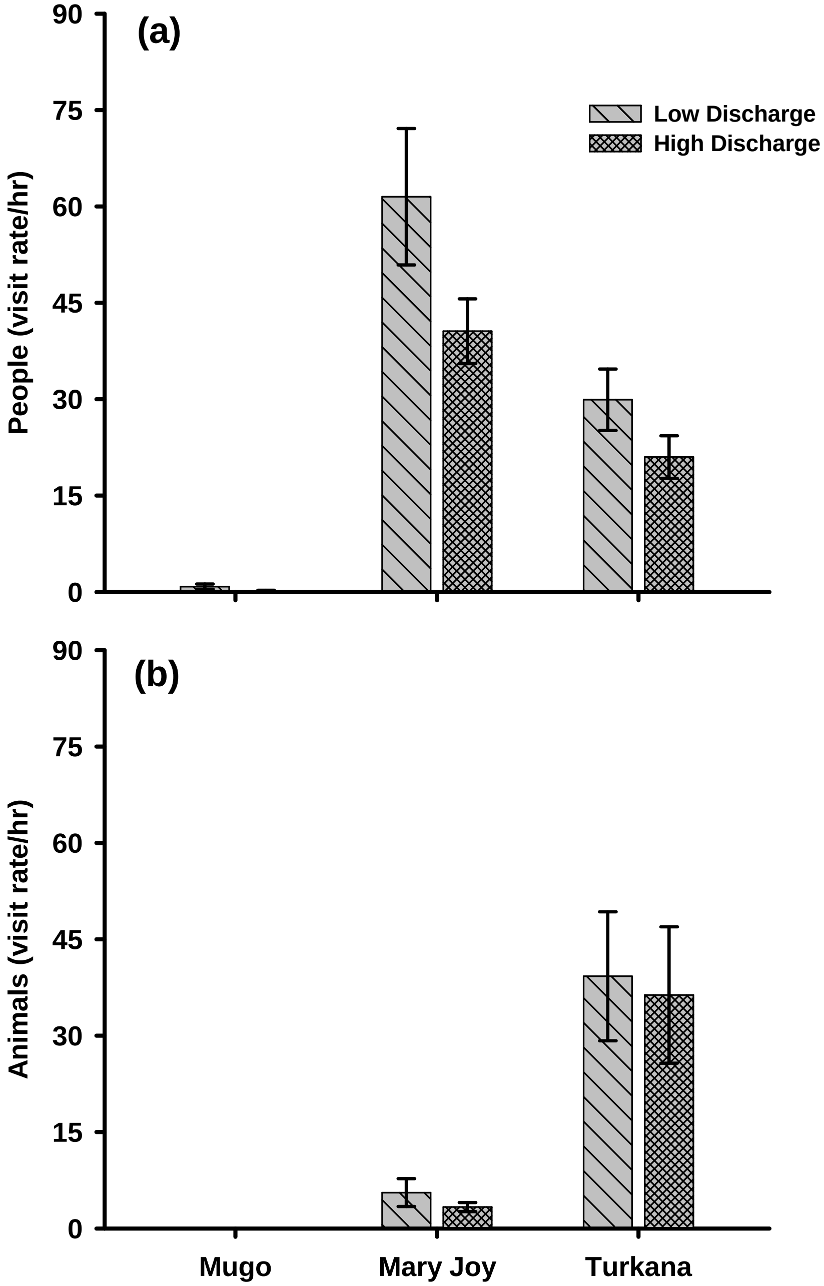

Figure 2: Visit rate by people (a) and animals (b) during low and high discharges at the three sites. Vertical bars are SE bars, n = 12.

Significantly, more people visited Mary Joy site than either Mugo or Turkana during low (One-Way ANOVA, $F_{(2,33)} = 118.822$, $p < 0.001$) and high (One-way ANOVA, $F_{(2,33)} = 188.739$, $p < 0.001$) discharges respectively. When animals were considered (Fig. 2b), significant differences were evident among the sites during low (One-way ANOVA, $F_{(2,33)} = 48.985$, $p < 0.001$) and high (One-way ANOVA, $F_{(2,33)} = 54.628$, $p < 0.001$) discharges respectively. Turkana was the most frequented site among the three (Tukey HSD, $\alpha = 0.05$). During both discharge regimes, men and women dominated at Mary Joy site while cows and sheep dominated at Turkana site (Fig. 3a and b). Few people visited Mugo and none of the animals were observed at this site during the entire period of study. Most of the activities that were observed included linen washing, bathing, river crossing and fetching of water. Women and children engaged in fetching water as well as linen washing at Mary Joy during low and high discharge regimes (Table 2). At Turkana site, men and children were mostly involved in water fetching and bathing. Most of the crossing was done by children at Turkana during low discharge.

The mean number of containers (20L) used to fetch water during low discharge was19.06 ± 3.58 while during high discharge was 15.75 ± 3.05SE. These two means did not differ significantly ($t = 0.703$, d.f = 70, $p > 0.05$). A similar observation was made when mean number of 100L drums were considered ($t = 0.781$, d.f = 70, $p > 0.05$) between low (2.89 ± 0.65) and high (2.19 ± 0.61) discharges respectively. During low discharge the mean number of 20L containers in use were significantly higher than the 100L containers ($t = 4.446$, d.f. = 70, $p < 0.001$). A similar observation was made during high discharge ($t = 4.357$, d.f. = 70, $p < 0.001$). The 20L containers were mostly used at Mary Joy site than any other site while the drums were used to ferry water at Turkana site.

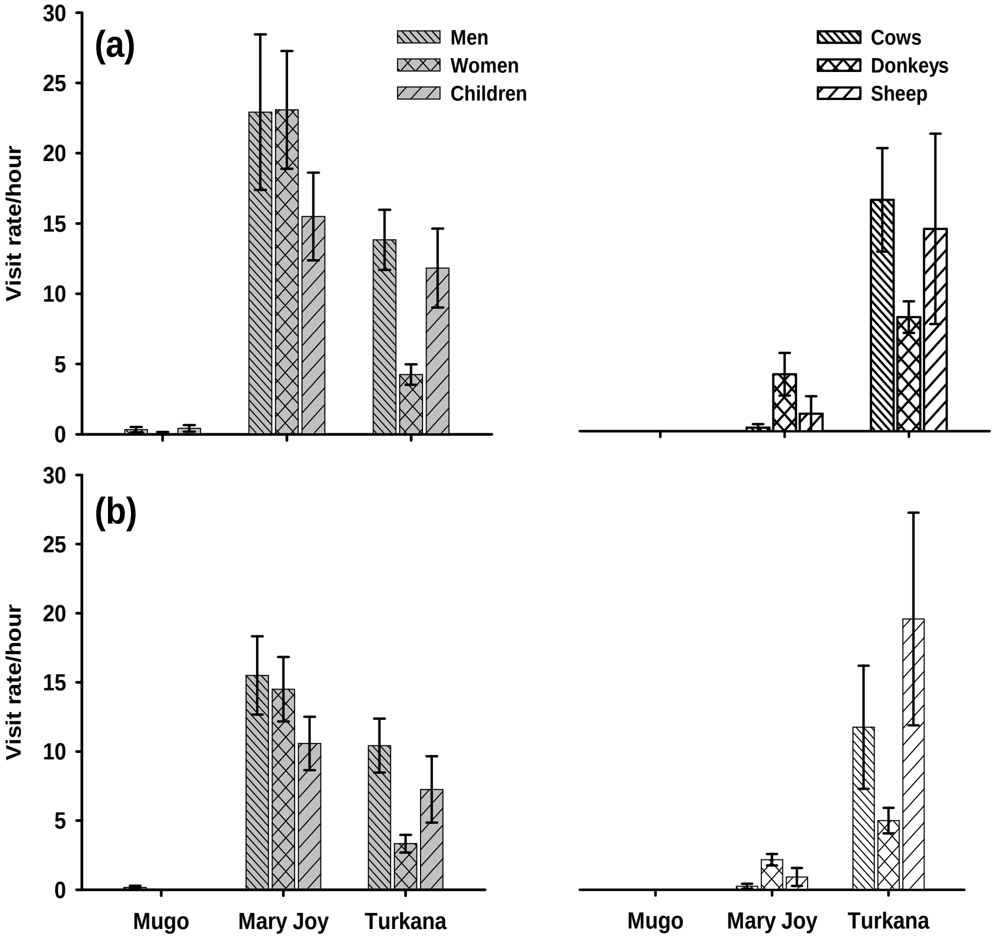

Figure 3: Visit rate during low (a) and high (b) discharges by various categories of people and animals. Vertical bars are SE bars, n = 12.

Table 2: Activities carried out at three sites in the middle reaches of the Njoro River during low and high discharges

Sites	Category	LOW DISCHARGE				HIGH DISCHARGE			
		Activity				Activity			
		Fetching water	Linen Washing	Crossing	Bathing	Fetching water	Linen washing	Crossing	Bathing
Mugo	Men	**0.08** (0.08)	**0.00** (0.00)	**0.00** (0.00)	**0.25** (0.13)	**0.17** (0.11)	**0.00** (0.00)	**0.00** (0.00)	**0.00** (0.00)
	Women	**0.08** (0.08)	**0.00** (0.00)	**0.00** (0.00)	**0.00** (0.00)	**0.00** (0.00)	**0.00** (0.00)	**0.00** (0.00)	**0.00** (0.00)
	Children	**0.00** (0.00)	**0.00** (0.00)	**0.33** (0.22)	**0.08** (0.08)	**0.00** (0.00)	**0.00** (0.00)	**0.00** (0.00)	**0.00** (0.00)
Mary Joy	Men	**7.08** (1.65)	**0.83** (0.83)	**0.00** (0.00)	**15.00** (4.69)	**6.33** (0.96)	**0.50** (0.23)	**0.00** (0.00)	**8.67** (2.35)
	Women	**11.17** (2.21)	**3.33** (1.47)	**0.00** (0.00)	**8.58** (2.91)	**8.50** (1.64)	**2.17** (0.71)	**0.00** (0.00)	**3.83** (1.42)
	Children	**7.33** (1.53)	**2.58** (1.57)	**0.00** (0.00)	**5.58** (2.68)	**8.92** (1.24)	**0.33** (0.22)	**0.58** (0.40)	**3.17** (1.22)
Turkana	Men	**8.08** (1.14)	**0.50** (0.29)	**0.00** (0.00)	**5.25** (1.51)	**6.92** (1.49)	**0.25** (0.18)	**0.08** (0.08)	**3.17** (0.87)
	Women	**1.75** (0.51)	**0.25** (0.18)	**0.00** (0.00)	**2.25** (0.73)	**1.75** (0.49)	**0.33** (0.14)	**0.00** (0.00)	**1.25** (0.48)
	Children	**6.83** (1.30)	**1.17** (0.58)	**1.17** (0.58)	**3.33** (1.45)	**2.92** (1.20)	**2.33** (1.48)	**0.00** (0.00)	**1.92** (0.66)

Discussion and Conclusion

Disturbances in aquatic systems are diverse and their impacts are mostly negative ranging from water quality deterioration to decimation of benthic animals (Parker & Huryn, 2011). Lotic systems offer the best opportunity to evaluate the impact of disturbances owing to their hierarchical organization from microhabitat system to stream systems (Frissel, *et al.*, 1986). Disturbances can thus be localized at microhabitat scale or spread at catchment or basin levels (Wang, *et al.* 2006; Malony & Weller, 2011). Recovery of benthic invertebrates is closely linked with the level at which disturbance occurs including its duration. Organism recover fast at localised disturbances that are short-lived and instantaneous (Lake, 2000). Nutrient inputs, sedimentation, pesticide application and logging are some of human disturbances that are well document in streams and rivers (Vasconcelos & Melo, 2008; Pliūraitė & Mickėnienė, 2009; Egler, *et al.*, 2011).

Visit rates at the three sites in the Njoro River by humans ranged from 20.6 – 30.8 while that by animals ranged between 13.2 and 15.0 per hour irrespective of the discharge regime. This translated to about 26 persons per hour and 14 animals per hour. When translated to 12hr period, then 312 individuals and 168 animals visited the river. On monthly basis approximately 9360 individuals and 5040 animals come to the river. The combined effect of such constant visits could be unstable banks, reduced grass cover promoting soil erosion and sedimentation. Vasconcelos & Melo, (2008) found that short term sedimentation in Forqueta River caused changes in benthic macroinvertebrate community composition and structure. M'Erimba, *et al.* (2006) attributed reduction in coarse particulate organic matter (CPOM) on the banks of Njoro River to constant trampling by humans and animals that visited the river. In another study, M'Erimba, *et al.* (2014) attributed reduction of benthic macroinvertebrates and diversity to human and animal induced disturbances that are common on the stream banks and stream channel.

Mathooko, (2001) working on a single impacted site on this river observed that the visit rates were patterned and seasoned becoming more intense during dry season than wet season. He attributed the difference to availability of water from the roof catchments during wet season. The insignificant difference observed between the rate of people and animals visiting the river during low discharge (dry season) and high discharge (wet season) could be attributed to population increase since 1994. Njoro River area has immense pressure on water resources and by year 2012 the population could have increased tenfold from what it used to be 19years ago. The number of students from a leading institution seeking for accommodation has also lead to increased land demarcation and continued construction of hostels within the riparian zones of this river and beyond. Water is drawn on daily basis for construction purposes using drums of 100L and sold at construction sites. The current study estimates that water abstraction is in the range of 315 – 381 using 20L containers and 219 – 298 L/h using 100 L containers (drums). On average, 278.25 L are abstracted per hour and 3339 L in 12 hours.

The activities observed during this study were varied and included water fetching, linen washing, bathing, river crossing and livestock watering. Direct washing in the river could be introducing phosphates directly into the river from the soaps. Mary Joy site that was close to a residential area was the most visited by men, women and children while Turkana site was mostly visited by livestock. Mugo site was less frequented by animals and humans during this study. Lake (2000) categorised disturbances as pulse, press and ramp types. Those observed in the Njoro River could be classified as press type since they are on daily basis. And finally, sites along the Njoro River could be classified as less disturbed, moderate or highly disturbed based on the intensity of humans and animals visiting the sites as well as activities as indicated in Table 3.

Table 3: Classification of sites based on human and animal visit rates as well as other activities (Linen washing, bathing, crossing, water fetching) in the Njoro River

Sites	**Visit rate/h (humans)**	**Visit rate/h (animals)**	**Activities**	**Disturbance category**
Mugo	0 - 1	0	None (0 - 1%)	Less disturbed
Mary Joy	41 - 62	3 - 6	Minimal (1-30%)	Moderately disturbed
Turkana	21 - 40	36 – 40	> 30%	Highly disturbed

Mathooko (2001) observed that disturbances that are intense reduced habitat diversity and consequently the diversity of macroinvertebrate assemblages in the same river. It is recommended that human/animal-water interaction should be minimized at Turkana site to allow for recovery.

Acknowledgement

Assistance offered by Mr. Edward Obong'o in census is highly appreciated. This project was funded by Egerton University through research fund grant.

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