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ASSESSING HUMAN IMPACTS ON THE GREATER AKAKI RIVER, ETHIOPIA USING MACROINVERTEBRATES

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ABSTRACT: We assessed the impacts of human activities on the Greater Akaki River using physicochemical parameters and macroinvertebrate metrics. Physicochemical samples and macroinvertebrates were collected bimonthly from eight sites established on the Greater Akaki River from February 2006 to April 2006. Eleven metrics representing richness, composition and tolerance/intolerance measures and which were thought to reveal changes along the river, were considered for the study. There was change in macroinvertebrate community structure as one proceeded from the upper reaches to the lower reaches along the Greater Akaki River. The upper reaches were characterized by greater number and diversity of taxa while the middle and lower reaches were dominated by fewer tolerant taxa. Spearman correlation analysis showed that metrics, expected to decrease with perturbation, had strong negative relationship with nutrients and measures of biological and chemical oxygen demand. Among the nutrients, most of these metrics had strong negative relationship with Ammonia. Change in structural organization of macroinvertebrates was attributed to nutrient enrichment and oxygen depletion. The study revealed that raw sewage and solid waste from residential and commercial centres, and runoff from impervious surfaces are responsible for the impairment in Greater Akaki River.

Key words/phrases: Benthic macroinvertebrates, Greater Akaki River, nutrient enrichment, oxygen depletion

INTRODUCTION

The impact of humans on water resources takes different forms. It includes physical alteration, and pollution from industries and residential areas (Chu and Karr, 2001). Also, it includes changes in riparian vegetation and stream morphology, sedimentation, nutrient additions, organic enrichment and pesticide contamination from agricultural land uses (Whiles *et al*., 2000).

In the last two decades, there has been a growing interest to use the biota as indicators of human impact on aquatic systems. This is partly attributed to the inadequacy of physical and chemical methods to measure impacts from non-point sources such as urban areas. Karr and Chu (2000) contend that in terms of indicating watershed conditions, biological communities are better than chemical and physical measures because they respond to the entire range of biogeochemical factors in the environment. However, there is a growing recognition among the academia and water resource managers that biomonitoring and bioassessment methods are complementary to that of traditional physical and chemical methods of evaluating human impact on aquatic systems (Linke *et al.,* 1999). When used together with chemical, physical and toxicological assessment tools, they greatly increase the ability to identify and quantify associated causes and sources (Yoder and Smith, 1999). Moreover, bioassessment methods are cost-effective (Yoder and Rankin, 1995) and often have low technical requirement which makes them useful especially to developing countries (Thorne and Williams, 1997). Benthic macroinvertebrates have been used in several biomonitoring and bioassessment programs (Barbour *et al*., 1996; Fore *et al*., 1996; Klemm *et al*., 2003). According to Barbour *et al.* (1999), macroinvertebrates are relatively easy to identify to family level, are good indicators of localized conditions and integrate the effects of short-term environmental variations, among others. In

Ethiopia, there were some efforts to use macroinvertebrates in river water quality studies. For example, Tesfaye Berhe *et al.* (1989) studied the trends of macroinvertebrate species and physicochemical parameters along the Abo-Kebena River system while Worku Legesse (2001) tested the sensitivity of some macroinvertebrate indices developed elsewhere in Kebena and Awetu Rivers. However, there is a need to establish the relationship between macroinvertebrate metrics and physicochemical parameters so as to identify the major stressors in the watershed. This information is of paramount importance to water resource managers and environmental agencies that envision rehabilitation of the Greater Akaki River. This study assesses the impacts of human activities on the Greater Akaki River using changes in macroinvertebrate community structure and the relationship between macroinvertebrate metrics and physicochemical parameters as indicators.

MATERIALS AND METHODS

The study area

This study was carried out on the Greater Akaki River flowing through Addis Ababa City (Fig. 1). The headwaters of the Greater Akaki River begin at an elevation of about 3000 masl from the Entoto Mountains. The River consists of the tributaries found in the eastern part of Addis Ababa including Abo, Kebena, Ginfle, Bantyketu and Akaki. Greater Akaki flows southwards across the residential and commercial centres of Addis Ababa towards Lake Aba Samuel, an artificial reservoir 30 km south of the city. The study area lies between 2549 masl. at GA1 to 2057 masl at GA8 (Fig. 1). The in stream habitat of the river is dominated by cobble/riffle except the lower part which is characterized by sediment. Annual average temperature varies from 9.9 to 24.6°C (FEPA, 2002). The summer (*kiremt*) season which occurs from mid-June to end of September is responsible for 70% of the annual average rainfall of 1400 mm. The spring season covers the period from February to April while the remaining months of the year are generally dry (FEPA, 2002). The mean annual discharge of the Greater Akaki River is 8.86 m^3/s (Tamiru Alemayehu *et al*., 2005).

Eight sampling sites (GA1-GA8) (Fig. 1) 50 m in total length were established on the Greater Akaki River for physicochemical analysis and benthic macroinvertebrate assessment. Sites GA 1 and GA2 are located in the upper part of the river where the riparian vegetation is dominated by *Eucalyptus* tree. These sites are located in a relatively unpopulated area. Here, people use the water for washing their clothes and for bathing purposes. Sampling sites GA3 to GA6 are found along the stretch of the Greater Akaki River characterized by extensive human settlement and commercial activity. In these areas, the proportion of the built-up area is high. Riparian vegetation is limited to bushes and grasses except sparse vegetation of *Eucalyptus* trees at GA5, GA6 and GA7. Sampling sites GA7 and GA8 are found in Akaki town, an industrial town on the outskirts of southern Addis Ababa. GA7 receives effluents directly from the surrounding textile factories. At GA5, GA7 and GA8, there are vegetable farms irrigated with the Greater Akaki River water.

Physicochemical analysis

From February 2006 to April 2006, water samples were collected at all study reaches bimonthly (*i.e*., twice a month) together with macroinvertebrate samples. Water samples were collected in 1L polyethylene bottles and were taken to the Applied Microbiology laboratory of the Addis Ababa University and Water and Wastewater laboratory of the Addis Ababa Environmental Protection Authority, where they were analysed for Ammonia (NH_3-N), Orthophosphate (PO_4^{3-}), Sulphide (S^{2-}), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5) and Total Suspended Solid (TSS). NH_3-N, PO_4^{3-}, S^{2-} and COD were determined using spectrophotometer (HACH DR/2010 USA) according to HACH instructions. BOD_5 and TSS were determined using methods outlined in standard methods for examination of wastewater manual (APHA 1998). Temperature (T°) was measured using a handheld thermometer. A portable pH meter (Model HI 9024 HANNA) was used to measure pH.

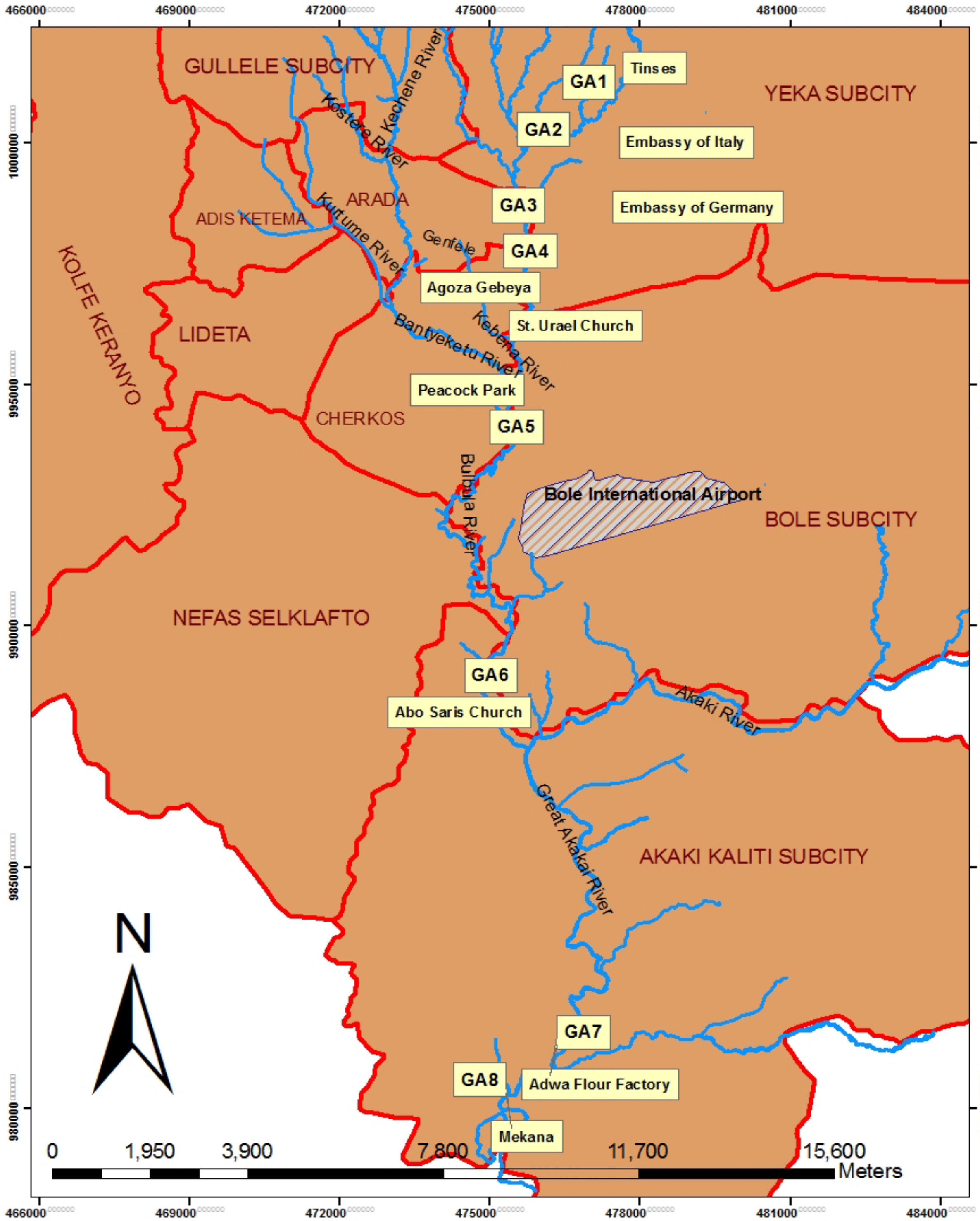

Fig. 1. Map of Addis Ababa City showing the Greater Akaki River and the study sites.

Macroinvertebrate sample collection and processing

Macroinvertebrate sampling was conducted bimonthly between February 2006 and April 2006 based on the method outlined in Barbour *et al.* (1999). Invertebrate samples were collected using Surber sampler (Mesh size = 500 µm, sampling area = 0.9 m^2) at riffle points by disturbing riffle substrate. Scoop net was used to collect invertebrates in pools. Samples from riffles and pools were composted on site and were preserved in 95% ethanol for later sorting and identification. In the laboratory, each sample was washed through a 500 µm sieve. Invertebrates were sorted in white trays, identified and counted under dissecting microscope. Taxonomic identification was made to family level using standard keys (Macan, 1979; Edington and Hildrew, 1981; Bouchard, 2004).

Eleven metrics representing richness, composition and tolerance/intolerance measures, which were thought to reveal changes along the Greater Akaki River, were considered for the study (Table 1). Chironomid metrics were not considered in the study because the Chironomidae family is known to include species with a wide range of tolerance values (Mykrä *et al.*, 2004). Moreover, trophic measures (feeding guilds) were not included because taxonomic identification was made to family level and different functional feeding groups might be present within the same family.

Statistical analysis

Spearman bivariate correlation analysis was used to relate benthic macroinvertebrate metrics to physicochemical parameters. All statistical analysis was performed using the SPSS statistical software (Version 12; SPSS Inc 2003).

RESULTS AND DISCUSSION

Trends in physicochemical parameters

The average values for the eight physicochemical parameters measured at eight sites on the Greater Akaki River are given in Table 2. pH did not show significant change throughout the study sites. Similarly, T° did not show significant change except a slight increase at GA7, probably due to hot effluents from the surrounding factories (Tamiru Alemayehu *et al.,* 2005). The mean concentrations of NH_3-N were significantly lower in the headwaters than the other sites, which were characterized by elevated levels especially GA5 and GA6. Sites GA5 and GA6 had also elevated PO_4^{3-} and BOD_5 levels. These sites are found after the point of confluence of the Abo-Kebena river system with Ginfle and Bantyiketu rivers, which for much of their length pass through the innermost sub-cities of Addis Ababa, namely Arada, Addis Ketema, Lideta and Kirkos. These sub-cities are densely populated and yet are poorly served with sanitation facilities and solid waste collection systems (UN-Habitat and CGAA, 2005), a possible explanation for the elevated levels of most nutrients and BOD_5 seen at GA5 and GA6. Increase in the proportion of impervious surfaces could also contribute to elevated levels of nutrients and BOD_5 by increasing surface runoff (Roy *et al*., 2003). In Addis Ababa, the problem is exacerbated by the poor drainage system that serves the city (UN-Habitat and CGAA, 2005). Thus, most of the *kirmet* rainfall water containing all sorts of wastes, including solid organic waste, sediments and nutrients, ends in the rivers. The mean concentrations of NH_3-N, PO_4^{3-} and BOD_5 decreased in the lower reaches (GA7 and GA8) after their peak values at GA5 and GA6, showing an improvement, albeit not significant, in the water quality downstream possibly from dilution effects of increased discharge. Tamiru Alemayehu *et al.* (2005) noted that the dominance of impervious surfaces, coupled with the altitude difference between upper and lower reaches, increased the discharge of rivers in Addis Ababa including the Greater Akaki River downstream. The average TSS concentration is high throughout the study sites with a moderate increase in the lower reaches. Surface runoff from impervious surfaces and erosion from riparian areas contributed to the high TSS recorded in the study sites. Study sites with some vegetation cover, such as GA1 and GA2, also had high TSS concentration. The dominant tree species in these study sites is *Eucalyptus*, which is often associated with limited undergrowth and erosion beneath tree stands (Legesse Negash, 2002). The mean TSS value for sites GA1 to GA5 was from 178.88 ± 46.67 mgl^{-1} to 197.5 ± 97.37 mgl^{-1} while for sites GA6 to GA8, the mean TSS varied from 214± 65.49 mgl^{-1} to 225 ± 82.24 mgl^{-1}.

Table 1. Definitions of metrics and expected direction of metric response to increasing perturbation for the Greater Akaki River.

Metrics	Definition	Expected response to increasing perturbation
No. taxa	Measures the overall variety of the macroinvertebrate assemblages	Decrease
No. Ephemeroptera taxa	Number of mayfly taxa	Decrease
No. Trichoptera taxa	Number of caddisfly taxa	Decrease
No. Diptera taxa	Number of "true" fly taxa, which includes midges	Decrease
No. Coleoptera taxa	Number of beetle taxa (adult or larva)	Decrease
% Ephemeroptera	Percent of mayfly nymphs	Decrease
% Trichoptera	Percent of caddisfly larvae	Decrease
% Diptera	Percent of dipterans	Increase
% Oligochaeta	Percent of aquatic worms	Increase
% Coleoptera	Percent of beetle larvae and aquatic adults	Decrease
% Dominant taxon	Measures the dominance of the single most abundant taxon	Increase

Table 2. Average physicochemical values (Mean± SE) in mgl^{-1}, except pH and T° (in °C) for the Greater Akaki River during February–April 2006 (n= 4).

Sites	Parameter							
	T°	pH	NH_3-N	PO_4^{3-}	S^{2-}	COD	BOD_5	TSS
GA1	18.25±0.96	7.57±0.25	0.15±0.19	1.16±1.04	0.03±0.01	73.75±17.17	2.67±2.12	182.83±61.22
GA2	18±2.83	7.56±0.05	0.14±0.08	1.18±0.90	0.05±0.06	49.75±8.38	4.1±2.77	187.45±68.46
GA3	17.25±1.26	7.34±0.26	16.48±2.39	4.27±1.05	0.04±0.03	51.5±16.11	13.75±4.99	197.5±97.37
GA4	16.25±1.26	7.13±0.36	14.8±1.75	6.78±0.91	0.03±0.04	106.25±15.76	13.25±4.99	188.83±63.58
GA5	16±0.82	7.17±0.29	21.35±2.97	9.67±0.63	0.08±0.05	137.25±46.7	36.52±11.09	178.88±46.67
GA6	19.75±1.71	7.58±0.42	27.5±1.27	9.14±1.44	0.02±0.07	180.75±6.55	50±18.26	220.7±48.72
GA7	21±1.41	7.58±0.02	10.95±1.57	4.16±1.67	0.02±0.01	190±6.0	10.7±1.54	225±82.24
GA8	19.25±2.06	7.09±0.55	12.05±1.64	2.22±1.54	0.05±0.04	59.75±19.91	4.93±3.62	214±65.49

Trends in Macroinvertebrate metrics

A total of 6618 macroinvertebrates, representing 27 families were collected from all representative study sites (Table 3). In the Greater Akaki River, the number of taxa was relatively high in the headwaters (GA1 and GA2) especially at GA1 compared to other sites. The relatively high number of taxa in the headwaters, especially GA1, is consistent with the expectation as the sites are found in areas where human influence is limited and the vegetation cover is high. As can be seen from Table 2, the water quality is also relatively good. Little change was noted in the number of taxa between GA2 and GA3.

In the remaining sites, the number of taxa decreased, with the lower river stretches characterized by fewer taxa (Table 3). Similar decreasing trends have been observed in other countries (Thorne and Williams, 1997; Ndaruga *et al.*, 2004).

The number of Ephemeroptera taxa was high (1050) at GA1 (Table 4). However, it sharply decreased at GA2 (283) and further decreased to fewer taxa in the middle reaches of the river, with no representation in the lower reaches (GA6 to GA8). Although two families of the Ephemeroptera taxa namely, Baetidae and Caenidae were identified, the number of Caenidae far exceeded that of Baetidae. The Trichoptera taxa were represented by the Hydropsychidae family only and were restricted to the headwaters. GA1 supported a larger number of Trichoptera taxa than GA2.

Table 3. Cumulative number of individuals for macroinvertebrate taxa collected at eight sites along the Greater Akaki River.

Taxon	Site							
	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8
Ephemeroptera								
Baetidae	77	47	19	14	1	0	0	0
Caenidae	973	236	6	2	0	0	0	0
Trichoptera								
Hydropsychdiae	87	9	0	0	0	0	0	0
Odonata								
Aeshnidae	2	2	0	0	0	0	0	0
Libellulidae	12	5	0	0	0	0	0	0
Coenagrionidae	1	0	0	0	0	0	0	0
Gomphidae	1	0	0	0	0	0	0	0
Coleoptera								
Gyrinidae	33	3	0	0	0	0	0	0
Dytiscidae	8	5	2	2	0	0	0	0
Hydrophilidae	14	8	1	0	0	0	0	0
Elmidae	7	1	0	0	0	0	7	1
Diptera								
Chironomidae	744	408	1082	125	70	146	613	71
Culicidae	14	0	170	0	1	4	3	0
Ceratopogonidae	26	0	21	0	0	0	0	0
Tipulidae	3	2	0	0	0	0	0	0
Simuliidae	0	34	0	0	0	0	8	0
Sciomyzidae	18	10	1	0	0	0	0	0
Psychodidae	3	3	68	19	105	22	3	3
Syrphidae	0	0	8	4	13	1	0	0
Ephydridae	0	0	10	0	1	0	0	0
Muscidae	0	0	2	0	0	0	0	0
Hemiptera								
Notonectidae	9	8	0	0	0	0	0	0
Corixidae	32	40	5	0	0	0	0	0
Oligochaeta	90	0	209	122	226	3	73	2
Turbellaria	18	0	0	0	0	0	0	0
Hirudinea	5	0	0	0	0	0	0	1
Gastropoda								
Physidae	0	0	74	222	53	0	0	1
Total Number of Taxa Collected over the sample period	22	16	15	8	8	5	7	6
Total Abundance	2177	821	1678	510	470	176	707	79

Table 4. Observed values for all metrics in the Greater Akaki River.

Metric	Site							
	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8
Total No. taxa	22	16	15	8	8	5	7	6
No. Ephemeroptera taxa	1050	283	25	16	1	0	0	0
No. Trichoptera taxa	87	9	0	0	0	0	0	0
No. Diptera taxa	808	457	1362	148	190	173	628	74
No. Coleoptera taxa	62	17	3	2	0	0	7	1
%Ephemeroptera	48	34	2	3	0	0	0	0
%Trichoptera	4	1	0	0	0	0	0	0
%Diptera	37	57	87	29	40	98	87	94
%Oligochaeta	4	0	13	24	48	0	10	3
%Coleoptera	3	2	0	0	0	0	1	1
%Dominant Taxon	48	47	65	44	48	83	85	90

The general decrease in the number of taxa and the disappearance of sensitive taxa, such as Ephemeroptera taxa and Trichoptera taxa in the lower reaches, could be attributed to catchment urbanization manifested in oxygen depletion, nutrient enrichment, and sedimentation in the study area. Although there is difference in the level of tolerance, most species of the Ephemeroptera and Trichoptera taxa are known to be intolerant to low dissolved oxygen (Welch, 1992). The Ephemeropera taxa and the Trichoptera taxa are also intolerant to nutrient enrichment. According to Allan (2004), nutrient enrichment stimulates primary production and authotrophic biomass, including algae growth especially in well lit rivers, may cause reduction in concentration of dissolved oxygen and hence a shift in macroinvertebrate structure and function. Miltner and Rankin (1998) observed a decrease in the number of the EPT (belonging to the Ephemeropera, Plecoptera and Trichoptera taxa) in relation to an increase in nutrient concentration in wadable streams. The proliferation of moss and algae, and the abundance of Physidae, a grazing gastropod at GA4 (Table 3), is a clear indication to nutrient enrichment in the Greater Akaki River.

The number of Diptera taxa changed along the Greater Akaki River but not in a consistent manner. Psychodidae, one of the most tolerant families among the Diptera taxa were found in all sites. However, their importance increased in the middle reaches. Syrphidae, another tolerant family was confined to the middle reaches. Although organic pollution and nutrient enrichment negatively affects the sensitive taxa, it seems that other taxa such as the Psychodidae family of the Diptera taxa benefit from the enrichment and were able to tolerate the low dissolved oxygen level. In fact, these organisms have some physiological and morphological adaptations that enable them to survive in anoxic environments (Welch, 1992). Mention should be made of the long respiratory tube of the rat-tailed maggots of the Syrphidae family, which gives them direct access to atmospheric oxygen (Bouchard, 2004).

The number of Coleoptera taxa at GA1 was relatively high and showed a remarkable decrease from GA1 to GA4. There were no Coleoptera taxa at GA5 and GA6 while GA7 and GA8 were represented by fewer number of Coleoptera taxa from the Elmidae family.

As regards the proportion of Ephemeroptera taxa, relative to the other taxa (*i.e.,* percent Ephemeroptera), their importance declined downstream, with no representation in the far middle and lower reaches. The lower reaches of the Greater Akaki River were dominated by fewer tolerant taxa mainly from the Diptera taxa, hence the increase in percent Diptera.

The significance of Oligochaete increased downstream especially in the middle reaches. A study by Walsh *et al*. (2001) showed that metropolitan communities (imperviousness 1–51%) were all severely degraded with high abundances of a few tolerant taxa compared to macroinvertebrate communities in the surrounding areas of Melbourne, Australia.

The high concentration of TSS throughout the study sites suggest that sedimentation could play an important role in shaping macroinvertebrate community structure in the Greater Akaki River. The biological effects of fine sediment are well-documented (Wood and Armitage, 1997; Nerbonne and Vondracek, 2001). By covering hard substrates and filling interstitial spaces, fine sediment makes movement and feeding difficult for many aquatic invertebrates including invertebrates that scrape algae from hard substrates.

Correlation between physicochemical parameters and macroinvertebrate metrics

Spearman correlation between physicochemical parameters and macroinvertebrate metrics is shown in Table 5. The results from the correlation analysis showed that at α =0.05, metrics expected to decrease with perturbation had a strong negative relationship with NH_3-N, PO_4^{3-}, COD and BOD_5. The metrics include: total number of taxa, number of Ephemeroptera taxa, number of Trichoptera taxa, percent Ephemeroptera, *etc*. The analysis further showed that most of these metrics had a stronger negative relation with NH_3-N than other parameters (Table 5). For example, total number of taxa (r = – 0.73), number of Ephemeroptera taxa (r= –0.67) and percent Trichoptera (r= –0.75). Miltner and Rankin (1998) reported that NH_3-N accounted for a significant portion of the variation in macroinvertebrate index scores in the headwaters and to a lesser extent, in wadeable streams in Ohio. The authors found that macroinvertebrate index scores at sites having concentration of NH_3-N≥ 1.0 mgl^{-1} were usually significantly lower than all other categories across stream size. Citing the loss of macroinvertebrate and sensitive fishes, Miltner and Rankin (1998) suggested involvement of chronic NH_3-N toxicity. In the Greater Akaki River, the mean concentrations of NH_3-N for the headwaters GA1 and GA2 was 0.15± 0.19 mgl^{-1} and 0.14±0.08 mgl^{-1}, respectively, whereas the mean concentration of NH_3-N for sites GA3 to GA8 ranged from 10.95 ± 1.57 mgl^{-1} to 27.5 ± 1.27 mgl^{-1}. The strong negative association between the sensitive macroinvertebrate taxa and NH_3-N, and the total disappearance of some macroinvertebrate species might suggest that in addition to eutrophication, chronic toxicity might be involved in the Greater Akaki River. We argue that, since the waters of some of the study sites, such as GA5 and GA6, are so dark in colour they would not get adequate light for eutrophication to happen at such a scale so as to cause the changes seen especially in these sites.

In this study, TSS showed moderate negative correlation with most metrics contrary to expectations. The explanations to this may be that the effect of TSS is overshadowed by nutrient enrichment and organic loading. pH and S^{2-} did not show significant relationship with any of the metrics. This may be due to their moderate and low values, respectively, in all the study reaches. Many Diptera and Ephemeroptera taxa, for example are affected at pH <5 (Johnson *et al.*, 1993). The mean pH value for all sites was ranging from 7.09 ± 0.55 to 7.58 ± 0.02. The range for mean S^{2-} was from 0.02 ± 0.01 mgl^{-1} to 0.08 ± 0.05 mgl^{-1}.

Table 5. Significant associations (tested at the α=0.05 level) between macroinvertebrate metrics and physicochemical parameters.

Metrics	Physicochemical parameters	r
Total No. taxa	NH_3-N	-0.73
	PO_4^{3-}	-0.64
	COD	-0.44
	BOD_5	-0.57
No. Ephemeroptera taxa	NH_3-N	-0.67
	PO_4^{3-}	-0.55
	COD	-0.43
	BOD_5	-0.53
No. Trichoptera taxa	NH_3-N	-0.75
	PO_4^{3-}	-0.69
	COD	-0.42
	BOD_5	-0.65
No. Diptera	PO_4^{3-}	-0.37
No. Coleoptera taxa	NH_3-N	-0.86
	PO_4^{3-}	-0.78
	COD	-0.40
	BOD_5	-0.73
%Ephemeroptera	NH_3-N	-0.74
	PO_4^{3-}	-0.61
	COD	-0.37
	BOD_5	-0.61
%Trichoptera	NH_3-N	-0.75
	PO_4^{3-}	-0.69
	COD	-0.42
	BOD_5	-0.65
%Diptera	T^o	0.53
%Coleoptera	NH_3-N	-0.90
	PO_4^{3-}	-0.84
	BOD_5	-0.82
%Oligochaeta	T^o	0.49
	PO_4^{3-}	0.45
% Dominant taxon	T^o	0.60

The critical temperature for most macroinvertebrates is 30°C (Welch, 1992). The T° measurement for all study reaches in the Greater Akaki River was below this threshold level. The range was 16 ± 0.82°C at GA5 to 21 ± 1.41°C at GA7. The slight increase in temperature downstream may have resulted in a strong positive association with the metrics that increase with perturbation such as percent dominant taxon (r=0.60). From the result, it appears that nutrient enrichment and oxygen depletion from organic loading are important in shaping macroinvertebrate community structure in the Greater Akaki River.

According to the river continuum concept (Vannote *et al.,* 1980), macroinvertebrate community structure and function change naturally along a river according to the stream order, which controls food supply, light and temperature. In this study, although we did not investigate changes in functional feeding groups, we argue that the changes in community structure observed in the Greater Akaki River could not be natural because of the total disappearance of the sensitive taxa and some other taxa, and the dominance of the few more tolerant taxa at downstream reaches.

Overall, this study showed that raw sewage and solid waste from residential and commercial centres of Addis Ababa, and runoff from impervious surfaces are responsible for the impairment in Greater Akaki River, and that changes in macroinvertebrate community structure are good indicators of impairment of river systems.

Moreover, the results from this study indicated that the factors affecting the Greater Akaki River are many and at times confounding. Therefore, water resource managers and environmental agencies aiming at rehabilitating the Greater Akaki River should give due consideration to the provision of sanitary facilities to riparian communities; improvement of sewerage system and wastewater treatment facilities; improvement of drainage system; riparian habitat management and solid waste management.

The scope of this study was limited to studying the structural changes in macroinvertebrate assemblage and relating selected macroinvertebrate metrics to some physicochemical parameters. Therefore, the study may not explain all the variations and the few exceptions observed in the study area. An integrated study that involves development of macroinvertebrate index and indices for other assemblages like macrophytes, periphyton, and a thorough quantitative habitat assessment (habitat scoring) should be considered in the future as such a study could give a complete picture of the factors affecting the Greater Akaki River.

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