



Assessment of aquatic Ecological health of three sites on Slacks Creek, Queensland, Australia using surface Macro invertebrates

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Abstract

The health of a river depends much on its riparian zone which is strategically positioned to lend them the capacity to influence aquatic processes. Plant communities in riparian zones provide adequate food resources for both terrestrial and aquatic consumers. The species diversity and richness is important for the health of the stream. The objective of the study was to make comparison of the ecological health status of three sites SC01, SC02 and SC03 of Slacks Creek, Queensland Australia which had different riparian conditions. The three sites had different riparian vegetation conditions. Surface water macro invertebrates were sampled at the three sites using standardized AusRivAS protocols. Both riparian vegetation condition and hydraulic characteristics were found to affect the abundance and richness of macro invertebrates in urban areas. Site SC01 and SC02 had relatively high oxygen concentration compared to SC03 whose water was not flowing. The pooled data established 12 taxa consisting of 258 individuals from the 9 samples. Specifically, SC03 had 8 taxa while SC01 and SC02 had 3 and 6 respectively and a Margalef Richness index of 0.64, 0.98 and 0.79 for SC01, SC02 and SC03 respectively. The three sites indicated some similarity at least as demonstrated by Bray Curtis Similarity indicator but SC03 was more dissimilar than the other two. The taxa found in the three sites were comparable with those established by South-east Queensland Ecosystem Health Monitoring Program (EHMP) studies. Site SC03 showed high macro invertebrates taxa richness, as it was a nutrient-poor water body and it was highly covered by submerged vegetation. Site SC02 had no riparian vegetation rehabilitation work had not prevented sediments from reaching the creek thus had higher nutrients accounting for less taxa. Site SC01 showed unexpected result of minimum taxa compared with site SC02, due to the canalization of the stream in upstream which leads to sediment transport to this site. This study showed that aquatic health of urban streams can be improved by providing them with buffering riparian vegetation.

Keywords: Ecological health, Riparian zone vegetation, surface water macro invertebrates, Slacks Creek.

Introduction

Over the last few decades there have been many studies focusing on aquatic ecological assessment. These studies have used both abiotic indicators^{1,2} and biotic indicators such as fish communities³, and macrozoobentos⁴. However all studies agree that the condition of the riparian zone is a major factor in determination of the health of a river system⁵. Gregory, Swanson⁶ and Naiman and Decamps⁷ define riparian zones to be small areas of land which are adjacent to the river and have biological connections with river biodiversity.

The health of a river depends much on its riparian zone which is strategically positioned to influence micro-climate, prevent nutrients transported from urban or agricultural areas reaching water bodies, serve as migratory routes and forest connectors, facilitate ground water recharge, moderate flooding, provide aesthetic values, regulate light and temperature regimes of streams and control the energy base of ecosystems, among other functions⁸. The roots of riparian vegetation help stabilize river banks and reduce bank erosion, which is evident in many urban streams where riparian vegetation has been removed⁹. The impervious surfaces of urban areas generate great runoff which

carries contaminants into streams causing them to be degraded¹⁰⁻¹². Groffman, Bulware¹³ and Greenway¹⁰ suggest that, the buffering capacity of riparian zones could filter the contaminants from the urban runoff before it enters the stream and reduce the volume of water entering through surface runoff. In addition, those urban streams which are lacking riparian buffer zones are not able to trap organic matter which supports in-stream nutrient processes¹⁴.

Plant communities in riparian zones provide adequate food resources for both terrestrial and aquatic consumers⁶. Bernhardt and Palmer¹⁵ indicate that urban streams are associated with reduced biotic activities. Nevertheless, Bernhardt and Palmer¹⁵ agree with other authors that vegetation in the riparian zones of urban streams is important, regardless of its width as it improves bank stability and enhances aquatic biodiversity in urban streams.

Species diversity and richness is important for the health of streams. Jonsson, Dangles¹⁶, while undertaking studies on the effects of species loss on the health of aquatic ecosystems using Amphipoda, Plecoptera and Trichoptera established that species numbers were important for detrital breakdown rates, although

only through species combinations as species richness per se showed no significant effect. In comparing the relationship between species richness and ecosystem multi-functionality, multi-functionality has been shown to rise incrementally with additional species which implies that ecosystem multi-functionality is well established by relatively more species in tropical areas¹⁷.

Sampling sites were selected as they depicted diverse riparian characteristics to indicate the impact of riparian vegetation on river system on urban landscape to provide a useful comparison in the analyses. Site SC01 had intact natural riparian vegetation, but upstream the river channel had been highly channelized. Site SC02 had no riparian vegetation. Site SC03 had intact riparian vegetation and was located in woody Karrawatha forest, but had a few residential houses about 30m away from it. Considering the health of the riparian zone it was expected that site SC01 and SC03 should have the highest diversity of aquatic macro invertebrates.

Material and Methods

Sampling sites were depicting diverse riparian characteristics were selected so as to determine the impact of riparian vegetation on river system in urban landscape and provide a useful comparison in the analyses. Surface water invertebrates were sampled at the three sites on 26th August, 2013 which was a spring season. The three sites chosen were of different characteristics but both of them on Slacks Creek. The sites' positions are given in table-1 and figure-1. Site SC01 had intact natural riparian vegetation, but upstream the river channel had been highly channelized. Site SC02 had no riparian vegetation. Site SC03 had intact riparian vegetation and was located in woody Karrawatha forest, but had a few residential houses about 30m away from it. Considering the health of the riparian zone it was expected that site SC01 and SC03 should have the highest diversity of aquatic macro invertebrates.

Table-1
Location of sampling sites on Slack Creek

Site	GPS reading		Description
	Latitude	Longitude	
SC01	27°38'S	153°7'E	End of Collard Street
SC02	27°37'S	153°7'E	End of Timothy Court
SC03	27°38'S	153°5'E	In Karrawatha Forest

The procedure used for data collection of aquatic macro invertebrates followed the standardized AusRivAS protocols as outlined in the Queensland AusRivAS Sampling and Processing Manual¹⁸. Dissolved oxygen and conductivity were taken just upstream of the sampling point where water was flowing except at SC03, which had no flowing water at all. This was in accordance with AusRivAS protocol¹⁸ which requires all water quality measurements to be collected upstream of the biological sampling area and of the water sample collected.



Figure-1
Sampling sites

The macro invertebrates were sampled using a standardized 250µm mesh dip net. The sampling distance was about 3m but covering different velocities of water and various habitats. Time taken for each sampling was 60 seconds to produce a representative sample. Three samples were collected from each site giving a total of 9 samples. For preservation purposes, 70% methylated spirit was used to preserve the samples in labeled plastic screw-top jars which were then delivered into the lab. Then the samples were picked out in the laboratory. This method was preferred as it saves time to be spent in the field as three sites had to be covered in one day. This was in accordance with AusRivAS protocol which allows either field or laboratory picking of specimens.

In the laboratory the preserved sample was thoroughly washed through a 1mm sieve. The washed samples were displayed on a sorting tray to be sorted under dissecting microscope and further preserved in bottles containing the 70% methylated spirit. Identification was done by use of stereo dissecting microscope according to families using standard identification keys, and abundance of each taxon counted.

The data collected was analyzed using both Microsoft Excel 2010 which gave graphs and trends, and Primer v6¹⁹ which gave tables for richness, abundance and similarity. In particular the indices used were Margalef richness, Shannon diversity and Simpson diversity which were supplemented by Bray-Curtis similarity distribution index and graphs. Gamito²⁰ argues that these indices are simple to use when combined as they are sensitive to evenness or change in dominant species. Bray-Curtis index indicates 0 where two sites are similar and 1 where they are dissimilar. It computes between sample dissimilarity coefficients before displaying sample patterns by non-metric multidimensional scaling (MDS)²¹. A cluster in the MDS presents biotic communities based on their overall resemblance to one another²². It calculates the dissimilarity matrix, select two

references points for determining direction of each axis and then projects all samples onto each axis by relationship to the two reference points²³.

Results and Discussion

Environmental conditions: There were two dominant environmental characteristic differences between the three sites under study. The first was the discharge characteristic of the creek and second was the condition of the adjacent riparian land. Within the area sampling was being done there was no river gauging station. However, at Site SC01 the creek was flowing stream despite the fact it had not rained for about six weeks, suggesting this is a nearly permanent site. The stream section comprised a series of riffles and pools. Due to the water flowing through the pools and riffles, oxygen concentration was 82.3% which was quite high (table-1). The site also had dense fringing riparian vegetation which appeared to be near natural, although the upstream section seems to have been interfered with by developing residential houses. There was a lot of woody debris in the stream (figure-1) which provided both in-stream habitat and carbon.

The second site, SC02, had very little flow of water but the riffles and pools were connected. Oxygen concentration was 70.4% which was also high as at SC01 (figure-1). However, in contrast to SC01, there was not much woody debris in the watercourse but emergent macrophytes were common. Mixing of the water was minimal due to low velocity of the little moving water. There was minimal to no riparian zone so the water course was exposed to direct sunshine, however, the site was part of a re-vegetation program. The creek had connected pools with no evidence of drying out. The sites planted with young vegetation are well protected to avoid sediments entering the river system.

Site SC03 was the source of Slacks Creek found in Karrawatha forest, which has not been influenced much by human activities. However, some residential houses could be seen on the left bank of the stream near the source. At this site, the riparian vegetation was intact, but the stream was not flowing. The pools of water were not connected but there were signs of being connected during the wet season. SC03 appeared to be different compared

with the other two sites, since the water was not flowing and algal growth was high, thus the macro invertebrates may have experienced disconnections during some parts of the year, unlike SC01 and SC02 which appeared to be connected throughout the year. The dissolved oxygen was very low (25.4%) which may also have contributed to differences between the sites.

Table-2
Dissolved oxygen and conductivity

Site	Dissolved Oxygen (%)	Conductivity (µS/CM)
Water quality guideline for Brisbane Creeks (DERM, 2009)	600	85-110
SC01	82.3	8.22
SC02	70.4	2150
SC03	25.4	106

µS/cm=micro Siemens per centimeter.

Description of communities: The pooled data established 12 taxa consisting of 258 individuals from the 9 samples taken in Slacks Creek (table 3) and only one family was in all sites.

Site SC01: Site SC01 had a total of 42 individuals from 4 taxa (table-3). Their abundance distribution was: Hydrobiidae (7%), Atyidae (31%), Ceratopogonidae (60%) and Hydroptilidae (2%). Insects dominated with a combined percentage of 62% in 50% of taxa. There were no Crustaceans observed.

Site SC02: In site SC02 a total of 105 individuals from 7 taxa were recorded (table-3). The taxa represented included; Baetidae (2%), Hydrobiidae (65%), Coenagrionidae (2%), Ceratopogonidae (21%), Hydroptilidae (6%), Gomphidae (2%) and Chironomidae (2%). At this site Hydrobiidae dominated while insects had only 36%.

Site SC03: Site SC03 was found to have a total of 114 individuals from 7 taxa (table-3). Their distribution was: Atyidae (88%), Chironomidae (2%), Baetidae (6%), Crustaceans (1%), Nepidae (1%), Hydrobiidae (1%) and Coenagrionidae (1%). Although >55% of taxa were insects, Atyidae tended to dominate the individual abundance in this site.

Table 3
Pool data indices matrix

	Richness	Abundance	Margalef Richness	Evenness	Shannon Diversity	Simpson Diversity
SC01	2	14	0.38	0.86	0.60	0.44
SC01	3	16	0.72	0.86	0.95	0.61
SC01	3	12	0.80	0.52	0.57	0.32
SC02	3	52	0.51	0.41	0.45	0.24
SC02	4	27	0.91	0.73	1.01	0.60
SC02	6	27	1.52	0.72	1.29	0.65
SC03	3	50	0.51	0.50	0.55	0.29
SC03	1	27	0		0	0
SC03	8	42	1.87	0.47	0.99	0.42

Comparison between sites: Site SC03 had the most abundant aquatic surface macro-invertebrates with a total of 119 individuals, while SC01 and SC02 had 42 and 106 respectively (table-4 and figure-2). In terms of taxa richness, SC01 had the least (3), followed by SC02 (6) while SC03 had the highest (8) (Table 4). On the other hand while using the Margalef Richness index, SC02 scored the highest (0.98), followed by SC03 (0.79) and as previously SC01 scores the lowest (0.64). The previous studies of EHMP had a lower abundance (60) and a higher richness (42) compared to sites SC01 and SC02 (figure-2 and figure-3). However Gamito²⁰ warns that Margalef Richness

index (d) is very sensitive to sample size and therefore should be used with absolute figures as was used in this case.

Data obtained from South-east Queensland Ecosystem Health Monitoring Program (EHMP) indicated long term trends for different species but Coenagrionidae and Atyidae were most abundant with high fluctuations (figure-4 and figure-5). The data also indicated that Hydrobiidae had declined over the years. The rest of the taxa were less abundant and showed little deviation in long term.

Table-4
Average indices per site

	Richness	Abundance	Margalef Richness	Evenness	Shannon Diversity	Simpson Diversity
Site 1	3	42	0.64	0.75	0.7	0.46
Site 2	6	106	0.98	0.62	0.92	0.5
Site 3	8	119	0.79	0.33	0.51	0.24

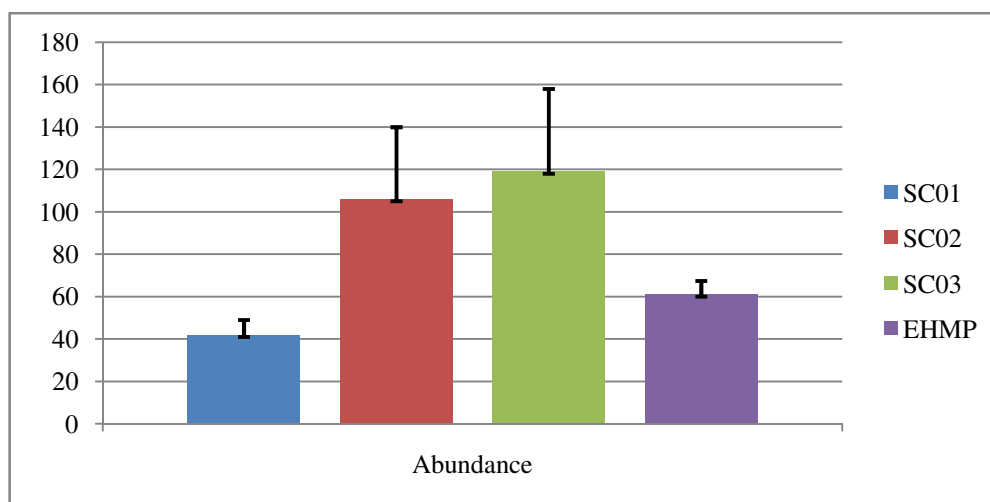


Figure-2
Taxa abundance of three sites in comparison to EHMP findings

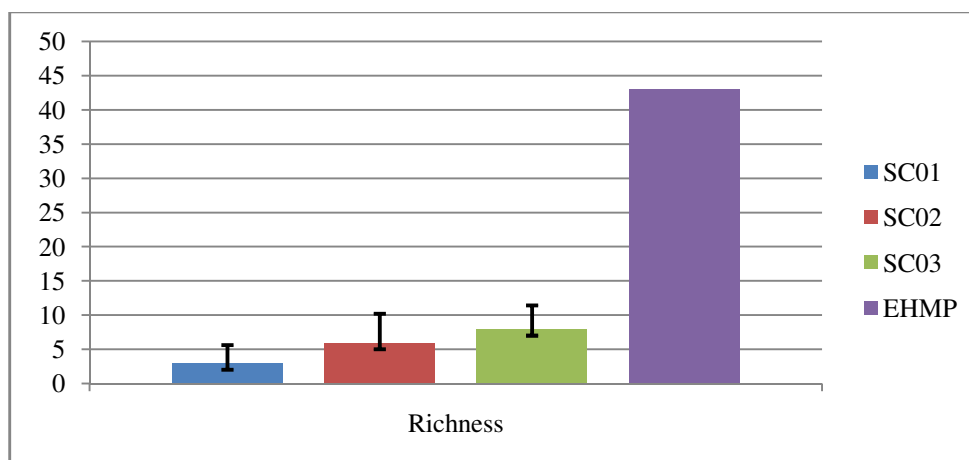


Figure-3
Taxa richness of three sites in comparison to EHMP findings

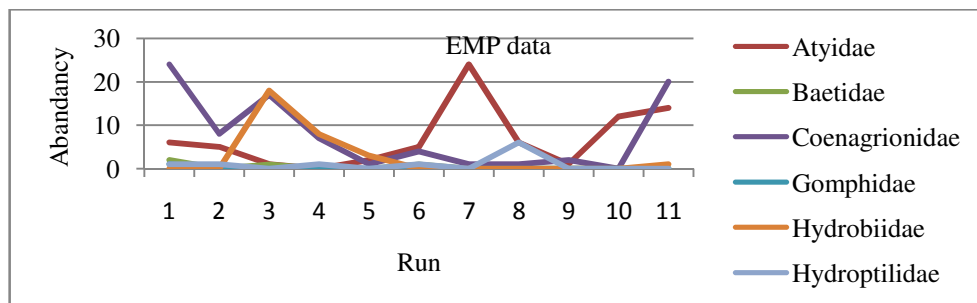
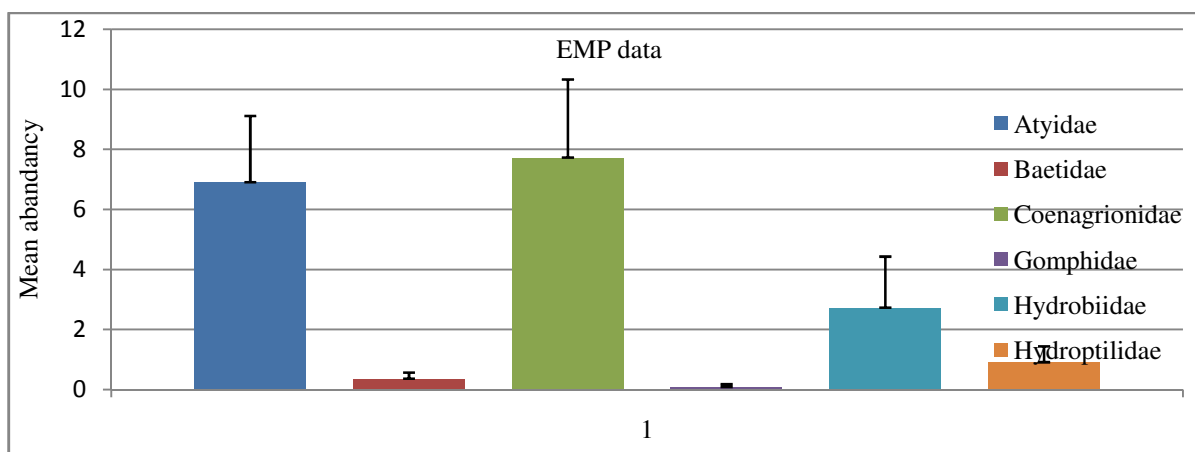


Figure-4
Taxa trends as observed from EHMP data Source



Source: Ecosystem Health Monitoring Data (2001-2008) (Sheldon pers com)

Figure-5
Mean abundance of taxa as observed from EHMP data

Shannon-Wiener²⁴ and Simpson²⁵ indices consider proportions and not absolute numbers²⁰. The data obtained portrayed quite a range of evenness with SC01 being most even with a score of 0.75, followed by SC02 with 0.62 and the least was SC03 with only 0.33 (table-4).

The diversity in the three sites was characterized using biodiversity measures. The two traditional methods, the Shannon index²⁶ and Simpson index²⁴ were applied as they characterize diversity basing it on the number of species present and their distributed per species (species evenness). Using the Shannon diversity index, SC02 scored the highest with 0.92, while SC01 and SC03 scored 0.7 and 0.51 (table-4). However as observed the range was not as wide as in the case of evenness. Simpson diversity index gave the same trend but with less values. Still SC02 scored the highest (0.5), followed by SC01 (0.46) and SC03 least (0.24).

Site similarity: The three sites indicated some similarity at least as demonstrated using the Bray Curtis Dissimilarity index (0.04) (figures-5 and 6). Site SC03 tended to differ most from the other two sites, having less than 20% similarity with either SC01 or SC02. The within site similarity of samples from SC03 was about 70%. Despite SC01 and SC02 being more similar to each

other than either was to SC03, they had only 40% similarity, suggesting there were still differences in community composition between these sites. The samples within SC02 tended to be about 50% similar. SC01 displaced unexpected result by one of its samples being 55% similar to SC02, while the other two samples were over 70% similar to each other. Generally there were no sites or samples which were 100% similar.

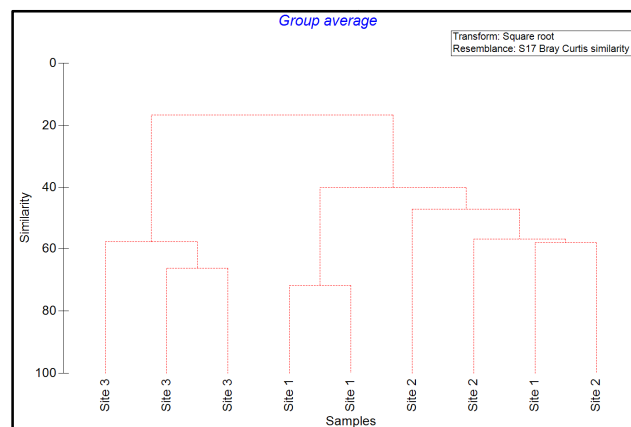


Figure-1
Bray Curtis Resemblance diagram

The three sites were distinctly different in their commonality composition as shown by distinct groupings on the MDS plot below.

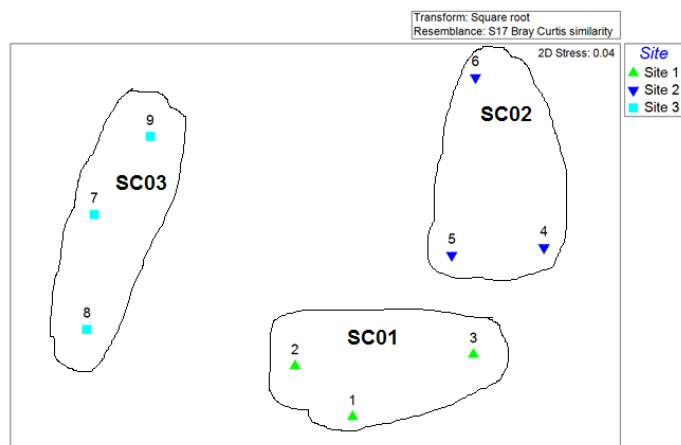


Figure-2
Bray Curtis Resemblance distribution

Discussion: Samples from Slacks Creek taken in-stream in August 2013 contained 12 surface invertebrate taxa. These taxa are comparable to those observed in the EHMP studies though with less taxa richness due to number of times samples were taken. This poses a challenge in comparison with other rivers and creeks under different studies in South East Queensland and other parts of the world. Sheldon and Walker²⁷ caution that data obtained by different methods, different times and different flow conditions may be misleading in making comparisons of different rivers. But comparing the water quality values for each site with DERM²⁸, all of them were much below the standards although site SC03 was the worst (table-1).

In both sites, one taxon dominated the others. In Site SC01 Ceratopogonidae composed more than 70% of the individual population, while in SC02 and SC03 Hydrobiidae and Atyidae respectfully presented more than 70% of the population (appendix-1). Site SC02 and SC03 had more diverse and abundant macro invertebrates compared to site SC01. This was unexpected result since SC01 had more intact riparian vegetation than especially SC02. This may have been caused by the oxygen demand in SC03 which was very high than other sites and Hydrobiidae are able to live in a wide range of habitats²⁹. The data was comparable with the findings of EHMP program however the study indicated a higher Hydrobiidae compared to the EHMP data. The three sites were distinct in terms of dissolved oxygen and conductivity which may have resulted to the observed distribution of macro invertebrates. Dissolved oxygen is also related to the biotic activities within the water system. At SC03 dissolved oxygen was low as the water was only found in pools which were not connected and respiration levels were obviously high. The algae blooms which could be observed must have consumed most of the oxygen leaving minimal remaining³⁰ as there was no water mixing as well. But due to the presence of intact riparian vegetation,

Atyidae (Fresh water shrimp) were the most common taxa. Newham, Fellows³¹ while studying the functions of the riparian forest in Bulimba Creek, South-east Queensland, Australia, established that the presence of riparian vegetation maintained low stream temperatures and low algal biomass, since shading reduces in-stream temperature fluctuation and algal production. They further established that in-stream shading from riparian vegetation was a limiting factor for in-stream primary production, rather than nutrient availability. Riparian forests make urban streams healthy compared to those with channels and no vegetation.

Site SC03 showed high macro invertebrate taxa richness, as the water body was highly covered by submerged vegetation. This site was characterized by herbivorous taxa such as Baetidae (Mayflies nymph) which live in cooler water and feed on algae, wood and aquatic plants; Crustaceans which feed on decaying vegetation; Chironomidae (Non-biting midge) which are detritivores feeding on a mixture of algae and bacteria; and Coenagrionidae (Dam flies nymph) which are short lived (8-10 weeks) which are able to live in ponds²⁹. This finding was consistent with Vermonden, Leuven³² who maintained that to optimize biodiversity in urban streams management should aim at lowering nutrient levels.

Site SC02 had no riparian vegetation as the replanting ones were still too young to have an impact. The creek at this site received considerable sediments from the surrounding land as the riparian zone is bare of vegetation. The banks have been protected by sisal mesh but still small gullies of erosion could be observed. But due to the flow of the water through pools and ripples, there was a considerable amount of dissolved oxygen which favored some macro invertebrates. The presence of dominance of Hydrobiidae is the result of this taxa being able to occur in huge quantities in variety of environments²⁹. The presence of Trueflies nymph (Ceratopogonidae) and dragonflies nymph (Gomphidae) in SC02 could be attributed by the fact that these two taxa prefer to burrow in the sand edges of rivers which are slow flowing, and areas where substrate is covered with detritus^{8,29}. This is consistent with the findings of Naiman and Decamps⁷ that the functions of riparian vegetation include regulation of nutrients, regulation of contaminants, maintenance of the microclimate which includes reduction of light levels, provision of energy flux and regulation of microbial processes. The restoration of vegetation on this site is also in line with the literature available which indicates that urbanization leads to ecosystem destruction, habitat fragmentation and species extinction^{33,34}. Savard, Clergeau³⁵ support that, restoration, preservation and enhancement of biodiversity in urban areas has gained momentum in the recent decades.

Site SC01 had only four taxa. The abundance of Trueflies nymph (Ceratopogonidae) followed by Atyidae (Fresh water shrimp) was attributed by the intact riparian vegetation which allowed them to burrow in the vegetated edges of river and also due to slow flowing of the streams at this site. The findings are

consistent with Gregory, Swanson⁶ who state that food used in stream and terrestrial ecosystems is ordinarily supplied by the adjacent terrestrial ecosystem in form of leaves and fruits while again providing habitat for prey. The great amount of sand observed in the creek may have been come from the upstream as evidenced from Google map (figure-2) which shows that there is no riparian vegetation covering the creek in some parts. The creek may be having a lot of nutrients making it unhealthy for most species.

Conclusion

Three sites SC01, SC02 and SC03 were studied in Slacks Creek. These sites had different riparian vegetation conditions. Both riparian vegetation condition and hydraulic characteristics were found to affect the abundance and richness of macro invertebrates in urban areas. Site SC01 and SC02 had relatively high oxygen concentration compared to SC03 due to non-flowing condition of water in SC03. The pooled data established 12 taxa consisting of 258 individuals from the 9 samples taken. Individually, SC03 had 8 taxa while SC01 and SC02 had 3 and 6 respectively and a Margalef Richness index of 0.64, 0.98 and 0.79 for SC01, SC02 and SC03 respectively. The three sites indicated some similarity at least as demonstrated by Bray Curtis Similarity indicator but SC03 was more dissimilar than the other two. The taxa found in the three sites were comparable with those established by EHMP studies. Site SC03 showed high macro invertebrate taxa richness, as it was a nutrient-poor water body and it was highly covered by submerged vegetation. Site SC02 has no riparian vegetation rehabilitation work has not prevented sediments from reaching the creek thus has higher nutrients accounting for less taxa. Site SC01 showed unexpected result of minimum taxa compared with site SC02, due to the canalization of the stream in upstream which leads to sediment transport to this site. This study showed that aquatic health of urban streams can be improved by providing them with buffering riparian vegetation. This study recommends detailed investigation on the appropriate riparian vegetation area extent required on either bank of Slacks Creek to maximize the benefits of riparian vegetation in improving aquatic health.

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