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An Assessment of Stream Health Through Use of Macroinvertebrates as Bio-Indicators

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ABSTRACT

The Stoney Creek Off-Channel Habitat Improvement Project aimed to restore a stream section in Burnaby, BC. The species assemblages of macroinvertebrate bioindicators were analyzed with reference to stream health of the restored ecosystem. Using a region specific B-IBI, species assemblages were characterized according to their tolerance to pollution. Samples where collected from a previously restored upstream site and recently restored downstream site and individually from riffle and pool zones within each site. Frequency distributions and relative abundances were used to measure actual and relative representation of categories. Overall, pollution tolerant species showed the highest representation over both sites when compared to pollution intolerant and somewhat tolerant species. Riffles exhibited a higher presence of pollution intolerant species then pools. These results indicate relatively low stream quality. Results of the WQI did not support the stream quality data provided by macroinvertebrates. Further study needs to be undertaken to involve baseline data and address additional determinants for species assemblages.

INTRODUCTION

The Stoney Creek Off-Channel Habitat Improvement Project conducted by the Stoney Creek Environment Committee (SCEC) was an intensive restoration project along Stoney Creek in Burnaby BC. The project involved the construction of 3 weirs to improve anadromous fish migration, reduce flow velocities, recruit gravel, provide spawning and pool habitat, back water off-channel pools intake, and reconnect the pond to the creek (Stoney Creek Environment Committee, 2012). SCEC has been involved in the protection and enhancement of Stoney Creek since 1995 and has on-going partnerships with City of Burnaby Parks, Metro Vancouver, DFO, as well as many community volunteers.

Stoney Creek is a viable salmon-bearing creek located in a largely urban area extending over 4km from Burnaby Mountain down to the Brunette River (Stoney Creek Environment Committee, 2012). Fed by groundwater, rain and snow, it meanders through Stoney Creek Park, and then runs through a ravine before flowing into the Brunette River. It is part of the Brunette watershed, which includes a number of other creeks. Prior to the restoration project Stoney Creek had been subject to many disturbances resulting in the erosion of substrate down to the sandstone bedrock (Ensing, 2013). The creek suffered loss of main stem diversity and limited off-channel habitat. The degraded habitat was unfavorable for spawning salmon and numerous other species, making it an important restoration target.

This report evaluates the stream quality and health in two restored areas of Stoney Creek using both a biological approach through the use of macroinvertebrates as bioindicators and a chemical approach through the use of a calculated water quality index (WQI). Efforts were focused in these reaches because they are the two main areas in which restoration took place, and are easily accessible.

The primary research questions include:

1. What is the level of diversity in the macroinvertebrate communities in both restored areas?
2. How does this reflect the level of health and quality of the stream?
3. What are recommendations for the future monitoring and maintenance of the restored reach?

Conducting such an assessment is important, as monitoring of the project is currently inadequate due limited resources (Stoney Creek Environment Committee, 2012). Assessments from this report can also be used to inform future restoration efforts.

METHODS

Ten samples were taken at two different sites. The first set of samples was taken at the Stoney Creek Ecological Restoration area located below Lougheed Highway (Figure A). This site has relatively little tree cover and is thus exposed to more sunlight. It also has relatively limited access. The second set of samples was taken a few kilometers upstream from the first site by the artificially constructed weirs below Beaverbrook drive (Figure A). This site is characterized by a greater amount of vegetation and tree cover, which provides more shade. However, it is more accessible due to its proximity to an urban trail. Both sites exhibit a similar morphology in having a steep slope on one side of the bank.

A 50m reach was measured and divided into 2m long plots for a total of 25 plots that covered the stream from bank to bank at each site. A random number generator was used to choose the sample plots. Within each sample plot, a riffle or a pool was sampled since these are known to contain different macroinvertebrate assemblages (Alvarez-Cabria et al., 2009). These were chosen based on availability so as to have five riffles and five pools per site and thus ensure representativeness. In both cases, the sampling began downstream and proceeded upstream in order to avoid disturbing the macroinvertebrates in the sediment. Square foot surber samplers were used to collect the samples of macroinvertebrates at the riffles and pools (McDonald, Mullins & Lewis, 1991). The species were then sorted and counted on site. A region specific Benthic Index of Biological Integrity (B-IBI) was used to classify macroinvertebrates into three pollution tolerance categories: pollution intolerant (category 1), somewhat tolerant of pollution (category 2) and pollution tolerant (category 3) (Appendix 1). A B-IBI was used as previous research has identified it as the most applicable index (Iliopoulou-Georgudaki et al., 2003). Microsoft Excel was used to analyze macro invertebrate community assemblages and create appropriate graphs.

Stream velocity was measured at each of the sample plots using the tennis ball method. Air temperature, water temperature, pH, total dissolved solids (TDS), dissolved oxygen and nitrogen and phosphate levels were measured at each of the two sites using a thermometer, pH meter, TDS meter, dissolved oxygen meter and nitrogen and phosphate testing kits. All of these measurements with the exception of air temperature were used to calculate the water quality index (WQI) for each site using an online calculator. Turbidity was not included in the WQI calculation given that the stream in both sites is relatively clear and thus, turbidity would not significantly influence the WQI.

RESULTS

Upstream and Downstream Sites

A frequency distribution showing the number of macroinvertebrates observed in each pollution tolerance category at each site was produced to provide an initial assessment of the macro-invertebrate assemblages (Figure 1). This indicated that there were more category 3 species (92 and 195 individuals), relative to category 1 and category 2 in both sites (25 and 7 individuals upstream, 43 and 13 downstream). As a means of addressing this difference, the relative abundances of invertebrate species in each category were calculated and compared (Figure 2). Measuring relative abundances provided a depiction of category representation related to the amount of species identified. This was important, as many more individuals were collected at the upstream site (124 individuals) as compared to the downstream site (251 individuals). Figure 2 showed that relative abundance in each category was only marginally different between sites.

Riffles

Further investigation required the separation of site assemblages into specific riffle and pools zones. Previous research has indicated that these zones are characterized by distinctive representation (Alvarez-Cabria et al., 2009). In the five riffle zones sampled per site, there was a higher representation of category 1 and category 3 species in the downstream site than the upstream site, as shown by the frequency distribution (Figure 3). Category 1 and category 3 downstream numbers of 33 and 78 and upstream numbers of 21 and 33 characterized this distribution. However, the relative abundances in riffles displayed largely equal presence of species between sites (Figure 4).

Pools

In the five pool zones sampled per site, a frequency distribution showed little representation of category 1 species in either site and a larger presence of category 3 species (Figure 5). Upstream, the category 1 and category 3 frequencies were 4 and 59 while their respective downstream values were 10 and 117. Using a relative abundance approach the assemblages are quite consistent between sites, but the relatively large presence of category 3 as compared to that of category 1 or 2 species is still noticeable (Figure 6). Abundances of upstream and downstream pool collections for category 3 individuals were 81.94% and 86.67% respectively.

Comparison of Riffle and Pools Per Site

Lastly the distribution of macroinvertebrate pollution tolerance categories of riffles and ponds within each site (Upstream and Downstream) were compared. Frequency distributions for both the upstream and downstream sites display a high representation of category 3 species in pools (72 and 117 individuals) and riffles (33 and 78 individuals). However, a higher representation of category 1 species, of

21 and 33 individuals, was noted in riffles when compared to pools with 4 and 10 individuals (Figure 7, Figure 8). This was also supported by the relative abundance comparisons (Figure 9, Figure 10), with marginally different relationships.

Additional Measurements

As a means of riffle and pool characterization, average velocity measurements were taken for each zone (Tables 1 and 2). Riffles, in general, displayed a higher average velocity than pools, as expected. The average velocities of many of the chosen pool locations were too slow to be appropriately measured by the tennis-ball method.

To support assemblage data, a water quality index (WQI) was created as a secondary means of evaluating stream health. The results of these chemical tests marginally differed between sites. This is reflected by the fact that the upstream and downstream sites had a WQI of 93 and 94 respectively (Tables 3 and 4). Table 5 displays the WQI categories, both of these values are considered excellent.

DISCUSSION

Upstream and Downstream Sites

In both the upstream and downstream reaches, category 3 had the greatest number of macroinvertebrates, followed by category 1 and then category 2. The number of macroinvertebrates in category 1 was considerably less than the number in category 3 (Figure 1). However, for all categories, the downstream reach had a greater total abundance of macroinvertebrates compared to the upstream reach. This may be due to the fact that the upstream site is more accessible to the public, and thus the macroinvertebrate community may experience greater levels of disturbance. Both reaches displayed similar relative abundances of macroinvertebrates among the pollution categories (Figure 2). This indicates that both stream sites have similar stream quality and health.

Riffles

When considering only the riffle sites sampled in the upstream and downstream reaches, category 3 was again the dominant category. However, in the upstream riffles, category 1 was better represented (Figure 3). This may be due to other factors influencing macroinvertebrate community assemblages such as higher levels of dissolved oxygen and available substrates found in riffles (Macdonald et al. 1991). This could also indicate that riffles represent less polluted areas in the stream. The riffles in the upstream and downstream reaches displayed the same relative abundance of macroinvertebrates (Figure 4).

Pools

When considering only the pools sampled in the upstream and downstream reaches, category 3 was again the dominant category. The number of macroinvertebrates in categories 1 and 2 was considerably lower than the number in category 3 in pool zones (Figure 5). The pools in the upstream and downstream reaches displayed the same relative abundance of macroinvertebrates (Figure 6). Additionally, category 1 had the lowest relative abundance among all categories (Figure 6). This evidence strongly suggests that pools represent more polluted areas of the stream.

Comparison of Riffles and Pools Per Site

Considering upstream and downstream sites independently, frequency distributions (Figure 7, Figure 8) and relative abundances (Figure 9, Figure 10) display higher representation of pollution intolerant species in riffles in comparison to pools. Pollution tolerant species where better represented in pools then riffles, while somewhat tolerant species had a minor representation in either zone. Therefore, both sites displayed similar stream quality.

WQI

The WQI was intended to support the findings of macroinvertebrate assemblages. However, the excellent WQI from both sites was not consistent with the overall high representation of pollutant tolerant macroinvertebrates in the stream. The inclusion of fecal coliform and biochemical oxygen into the WQI calculation may have additional, unaccounted for, impacts on the WQI result (Oram, 2013).

Limitations

This study is limited because of the assumptions necessary to perform the fieldwork. First, it was assumed that assemblages of macroinvertebrates were natural and undisturbed prior to sampling. The macroinvertebrates were identified to the best possible extent but misidentifications are a possible source of error. Many species that could have been mistaken for another were in the same category and therefore most misidentifications would not have significantly affected the results. The arbitrary selection of riffle and pool zones within each sample plot introduced a necessary source of bias. This was to ensure adequate representation of differing stream regions that may have been overlooked due to randomization. Additionally, some macroinvertebrates may have not been detected in the samples due to their size and tendency to blend in with the sediment. Detection was particularly difficult in some of the ponds due to high sediment content of the sample. Despite the limitations and assumptions, the results consistently showed that pollution tolerant macroinvertebrates (category 3) were most abundant throughout the stream. This supports the interpretation of overall stream quality and health.

CONCLUSION AND FUTURE MANAGEMENT

Using macroinvertebrates as bioindicators suggests that the relative health of the stream system appears to be poor. The lack of representation of pollution intolerant and somewhat tolerant species through all samples, along with the high abundance of pollution tolerant species, supports this evaluation. Increased velocity in the riffles was coupled with better relative representation of the pollution intolerant species. Additionally, the upstream area with higher human use exhibited evidence of lower water quality, possibly attributable to increased disturbance.

Without sufficient baseline data it is difficult to characterize whether improvement has occurred in response to restoration efforts. Macroinvertebrate data collected through this study indicates relatively low overall stream quality, which was not supported by the calculated WQI.

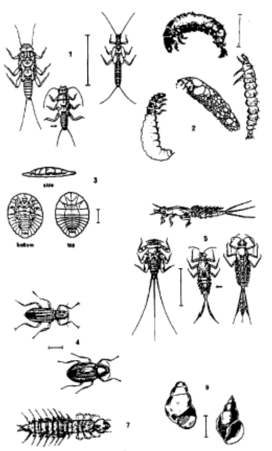
Further studies should compare these results to baseline data collected pre-restoration. This would allow for a more concrete determination of temporal change in assemblages and lead to conclusive evidence as to the actual stream health and success of the restoration project. Due to time constraints associated with data analysis, baseline data could not be prepared for this study. Additionally, given that multiple factors influence macroinvertebrate community assemblages, further studies should address these in detail. This could perhaps explain the discrepancy between macroinvertebrate community assemblages and the WQI found in this study. As shown by this study, the relative stream health is low and increased effort is necessary to obtain a better representation of pollution intolerant assemblages.

APPENDIX 1 – Macroinvertebrate identification sheet

The Stewardship Series

Appendix 1
Field Identification and Pollution Tolerance Chart

adapted from Save our Streams, Izaak Walton League of America



1 Stonefly:
Order Plecoptera
1/2" - 1 1/2", 6 legs with hooked tips, antennae, 2 hair-like tails. Smooth (no gills) on lower half of body. (see arrow)

2 Caddisfly:
Order Trichoptera
up to 1", 6 hooked legs on upper third of body, 2 hooks at back end. May be in a stick, rock or leaf case with its head sticking out. May have fluffy gill tufts on lower half.

3 Water Penny:
Order Coleoptera
1/4", flat saucer-shaped body with a raised bump on one side and 6 tiny legs on the other side. Immature beetle.

4 Riffle Beetle:
Order Coleoptera
1/4", oval body covered with tiny hairs, 6 legs, antennae. Walks slowly underwater. Does not swim on surface.

5 Mayfly:
Order Ephemeroptera
1/4 - 1", brown, moving, plate-like or feathery gills on sides of lower body (see arrow) 6 large hooked legs, antennae, 2 or 3 long, hair-like tails. Tails may be webbed together.

6 Gilled Snail:
Class Gastropoda
Shell opening covered by thin plate called operculum. Shell usually opens on right.

7 Dobsonfly (Helgrammite):
Family Corydalidae
3/4 - 4", dark coloured, 6 legs, large pinching jaws, 8 pairs feelers on lower half of body with paired cotton-like gill tufts along underside, short antennae, 2 tails and 2 pairs of hooks at back end.

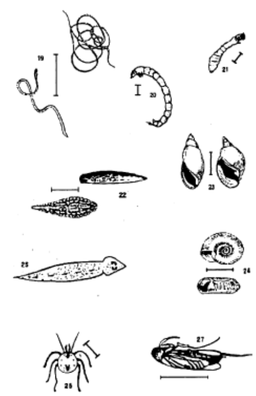
Category One Taxa
Pollution sensitive organisms found in good quality water

BAR INDICATES RELATIVE SIZE

Streamkeepers' Module 4 Stream Invertebrate Survey 17

The Stewardship Series

Appendix 1
Field Identification and Pollution Tolerance Chart, *(continued)*



19 Aquatic Worm:
Class Oligochaeta
1/4 - 2", can be very tiny, thin worm-like body.

20 Midge Fly Larva:
Suborder Nematocera
Up to 1/4", dark head, worm-like segmented body, 2 tiny legs on each side.

21 Blackfly Larva:
Family Simulidae.
Up to 1/4", one end of body wider. Black head, suction pad on end.

22 Leech:
Order Hirudinea
1/4 - 2", brown, slimy body, ends with suction pads.

23 Pouch Snail and Pond Snails: Class Gastropoda
No operculum. Breathe air. Shell usually opens on left.

24 Other Snails:
Class Gastropoda
No operculum. Breathe air. Snail shell coils in one plane.

25 Planarian:
Class Turbellaria
Flattened, unsegmented worm-like body, may have distinct eyespots, gliding movement.

26 Water Mite:
Order Hydracarina
Looks like spider, may be very tiny, has 8 legs.

27 True Bug Adult:
Order Hemiptera
Has short legs, swims or dives quickly.

Category Three Taxa
Pollution tolerant organisms can be in any quality of water

BAR INDICATES RELATIVE SIZE

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The Stewardship Series

Appendix 1
Field Identification and Pollution Tolerance Chart, *(continued)*

8 Crayfish: Order Decapoda
Up to 6", 2 large claws, 8 legs, resembles small lobster.

9 Sowbug: Order Isopoda
1/4 - 3/4", grey oblong body wider than it is high, more than 6 legs, long antennae.

10 Scud: Order Amphipoda
1/4", white to grey, body higher than it is wide, swims sideways, more than 6 legs, resembles small shrimp.

11 Alderfly larva: Family Sialidae
1" long, looks like small hellgrammite but has 1 long, thin, branched tail at back end (no hooks). No gill tufts underneath.

12 Fishfly larva: Family Corydalidae
Up to 1 1/2", looks like small hellgrammite but often a lighter reddish-tan colour, or with yellowish streaks. No gill tufts underneath.

13 Damselfly: Suborder Zygoptera
1/2 - 1", large eyes, 6 thin hooked legs, 3 broad oar-shaped tails, positioned like a tripod. Smooth (no gills) on sides of lower half of body (see arrow).

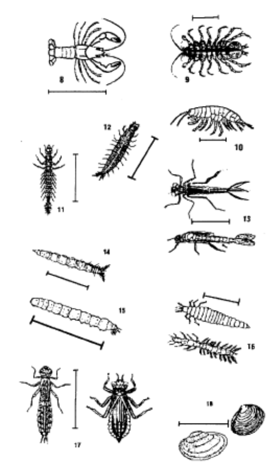
14 Watersnipe Fly Larva: Family Athericidae (Atherix)
1/4 - 1", pale to green, tapered body, many caterpillar-like legs, conical head, feathery "horns" at back end.

15 Crane Fly: Suborder Nematocera
1/3 - 2", milky, green, or light brown, plump caterpillar-like segmented body, 4 finger-like lobes at back end.

16 Beetle Larva: Order Coleoptera
1/4 - 1", light-coloured, 6 legs on upper half of body, feelers, antennae.

17 Dragon Fly: Suborder Anisoptera
1/2 - 2", large eyes, 6 hooked legs. Wide oval to round abdomen.

18 Clam: Class Bivalvia



BAR INDICATES RELATIVE SIZE

Category Two Taxa
Somewhat pollution tolerant organisms can be in good or fair quality water

18 Stream Invertebrate Survey Streamkeepers' Module 4

The Stewardship Series

send the data to: Streamkeepers Database

Invertebrate Survey Field Data Sheet
(use a new data sheet for each stream section surveyed) **Module 4**

Stream Name	Date
Stream Segment # Stream Section #	Sampling location
sampler used, mesh size, total area sampled	# of 30cm x 30cm samples

COLUMN A Pollution Tolerance	COLUMN B Number Counted	COLUMN C Number of Taxa	COLUMN D Common Name
CATEGORY 1 (pollution intolerant)			Caddisfly Larva (EPT)
			Dobsonfly (hellgrammite)
			Gilled Snail
			Mayfly Nymph (EPT)
			Riffle Beetle
			Stonefly Nymph (EPT)
			Water Penny
Sub-total			
CATEGORY 2 (somewhat tolerant of pollution)			Alderfly Larva
			Aquatic Beetle
			Aquatic Sowbug
			Clam, Mussel
			Cranefly Larva
			Crayfish
			Damselfly Larva
			Dragonfly Larva
			Fishfly Larva
			Scud
			Watersnipe Larva
Sub-total			
CATEGORY 3 (pollution tolerant)			Aquatic Worm
			Blackfly Larva
			Leech
			Midge Larva (chironomid)
			Planarian
			Pouch and Pond Snails
			True Bug Adult
			Water Mite
Sub-total			
TOTAL			

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APPENDIX 2 - Tables

Table 1 – Average velocity measurements for downstream site

Sample plot	Zone	Average velocity
25	Riffle	0.318181818
21	Pond	*
19	Riffle	0.29877369
16	Pond	*
10	Riffle	0.306791569
9	Riffle	0.217289171
8	Pond	0.131721478
7	Pond	0.116020985
4	Pond	0.344929245
3	Riffle	0.303099885

* velocity too slow to be measured

Table 2 - Average velocity measurements for upstream site

Sample plot	Zone	Average velocity
25	Riffle	0.183306056
22	Pond	0.204569055
21	Riffle	0.32782516
20	Pond	*
18	Riffle	0.440891473
17	Riffle	0.350985222
13	Riffle	0.435606061
4	Pond	*
3	Pond	*
1	Pond	*

* velocity too slow to be measured

Table 3 - Chemical test data and WQI for the downstream site

Chemical Test	Result	Q-value	Weighting factor	Index value
Total dissolved solids	90 ppm	84	0.07	5.88
Dissolved oxygen	95.60%	98	0.17	16.66
pH	6.9	86	0.11	9.46
Nitrate	1 ppm	96	0.10	9.6
Total phosphate	0 ppm	100	0.10	10
Temperature change	0.2°C	92	0.10	9.2
Based on the 6 factors above, WQI = 94				

Table 4 - Chemical test data and WQI for the upstream site

Chemical Test	Result	Q-value	Weighting factor	Index value
Total dissolved solids	90 ppm	84	0.07	5.88
Dissolved oxygen	97%	99	0.17	16.83
pH	6.7	79	0.11	8.69
Nitrate	0 ppm	97	0.10	9.7
Total phosphate	0 ppm	100	0.10	10
Temperature change	0.0°C	93	0.10	9.3
Based on the 6 factors above, WQI = 93				

Table 5 – Water Quality Index Legend

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

APPENDIX 3 – Figures

Figure A – Stoney Creek from Beaverbrook Drive to Government Road. The creek and tributaries are shown in blue, and they yellow highlighted sections identify sample sites. Courtesy of the Stoney Creek Environment Committee (2012).

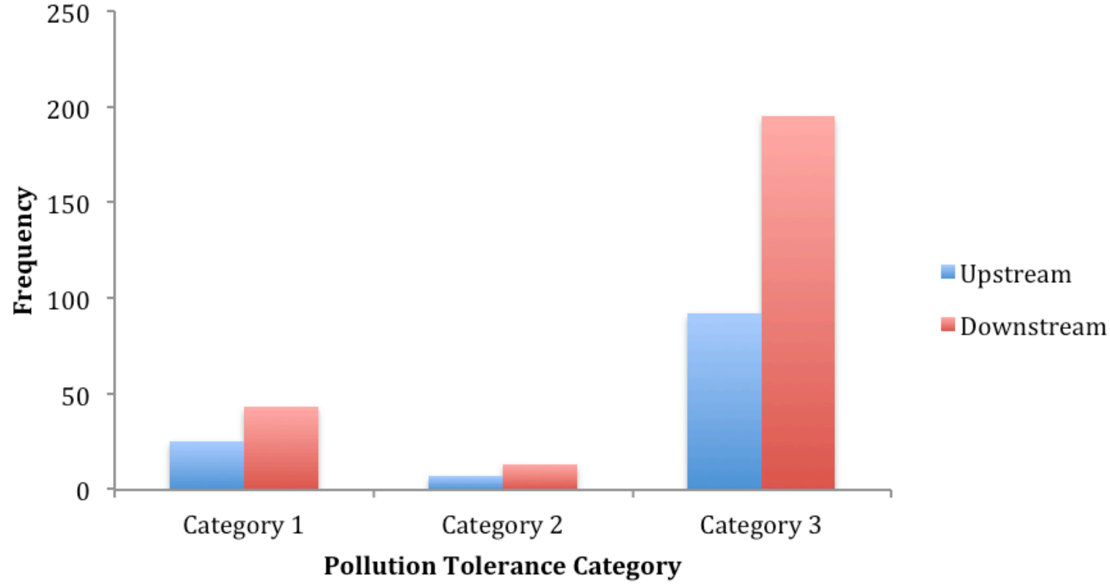

Figure 1 – Frequency distribution of species assemblages for the upstream and downstream sites.

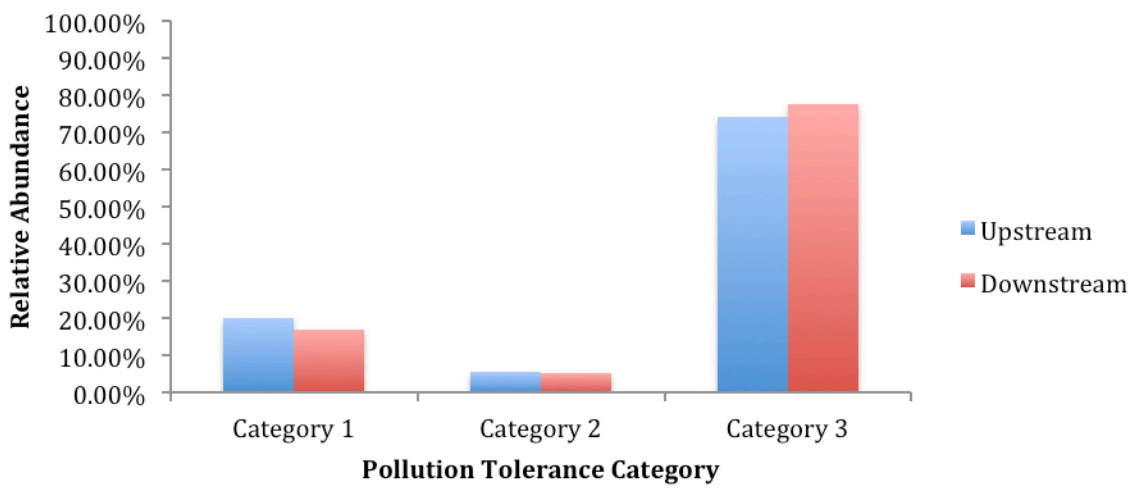

Figure 2 – Relative abundances of species for the upstream and downstream sites.

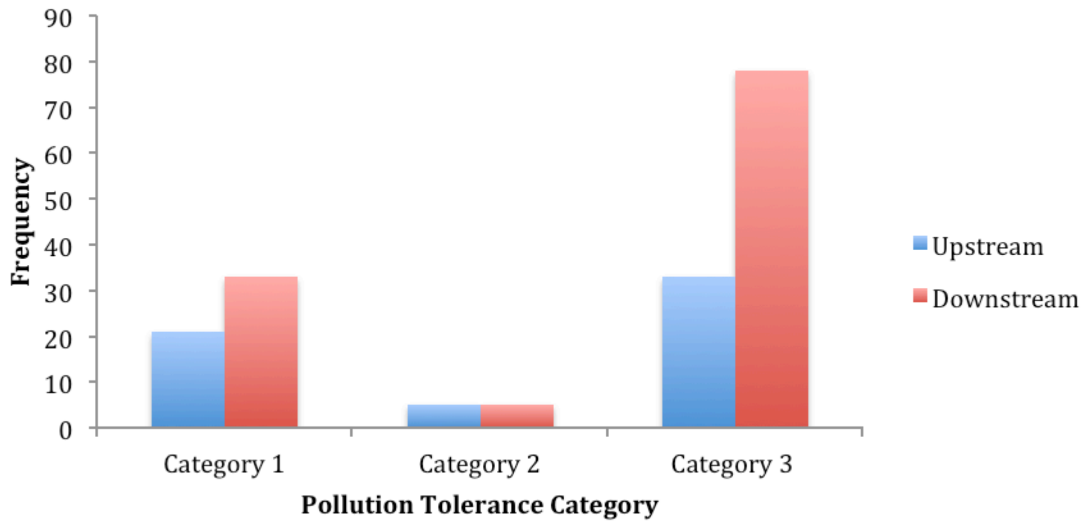

Figure 3 – Frequency distribution for species assemblages in the riffle zones of upstream and downstream sites.

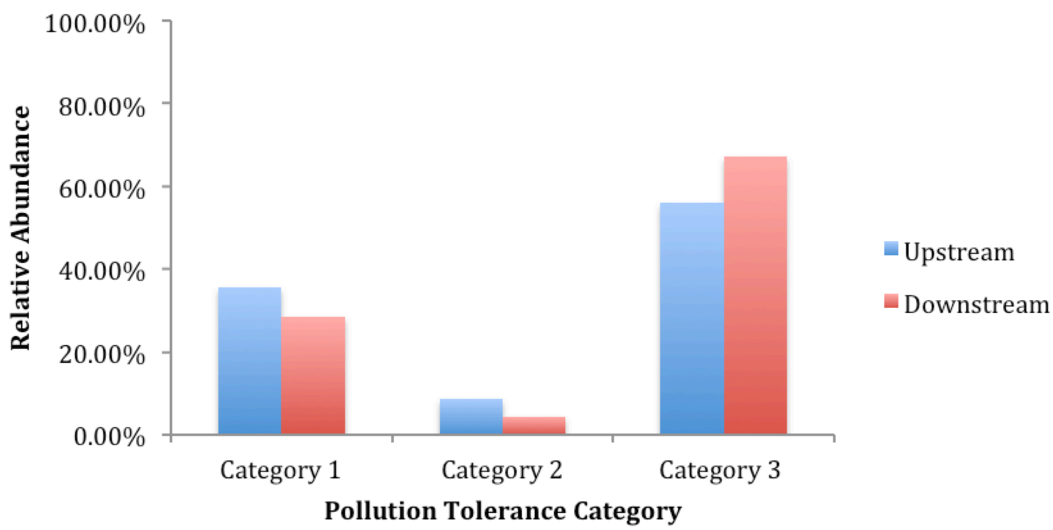

Figure 4 – Relative abundance of species in the riffle zones of the upstream and downstream sites.

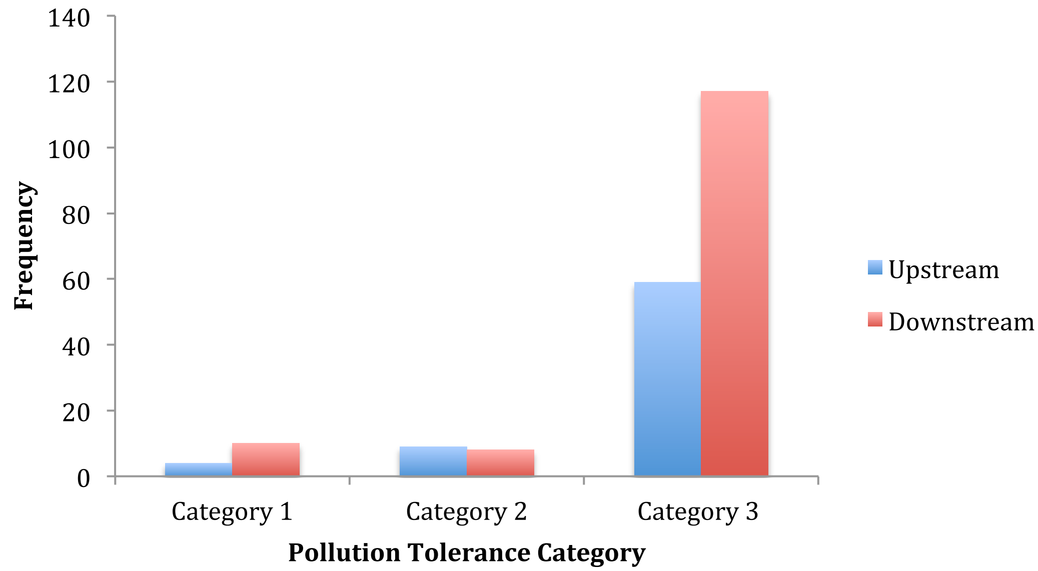

Figure 5 – Frequency distribution for species assemblages in pond zones of upstream and downstream sites.

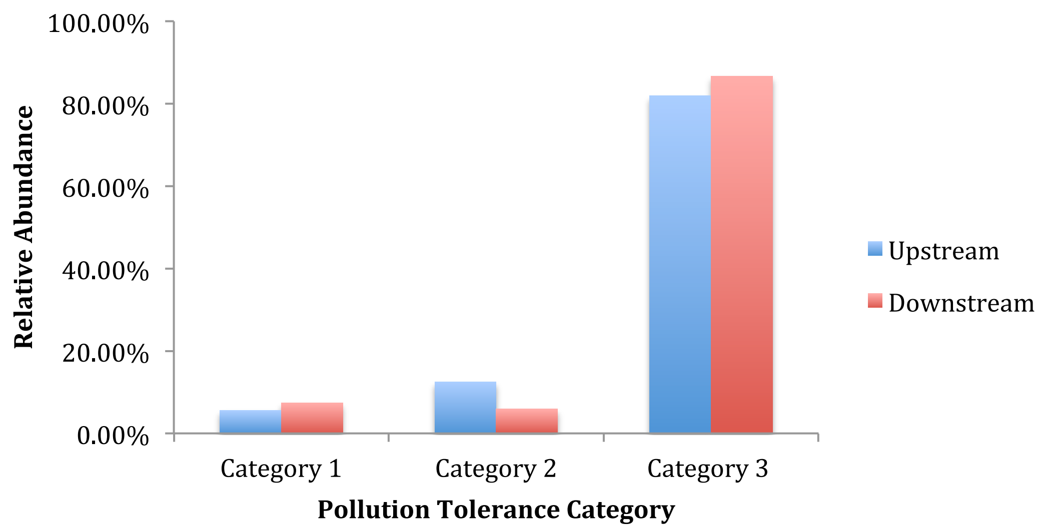

Figure 6 – Relative abundances for species in the pond zones of upstream and downstream sites.

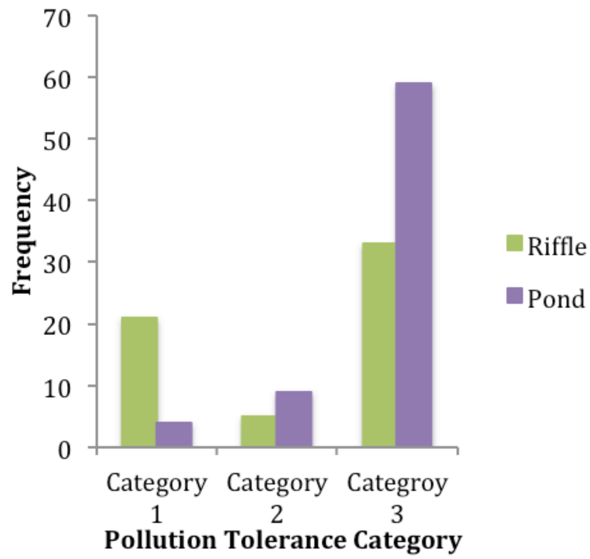

Figure 7 – Frequency distribution of riffle and pond assemblages for the upstream section.

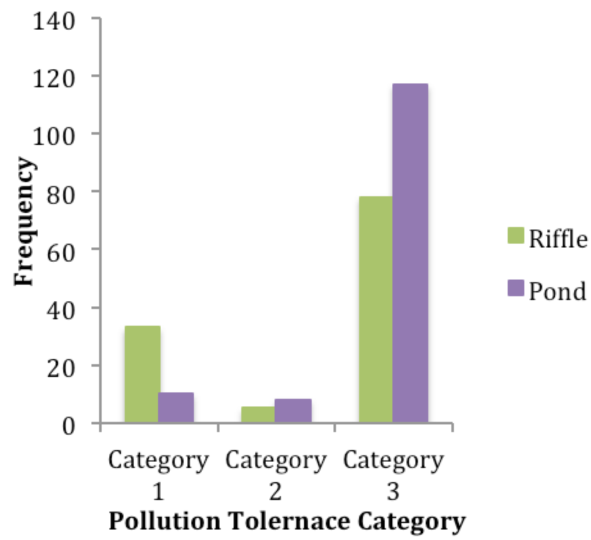

Figure 8 – Frequency distribution of riffle and pond assemblages for the downstream section.

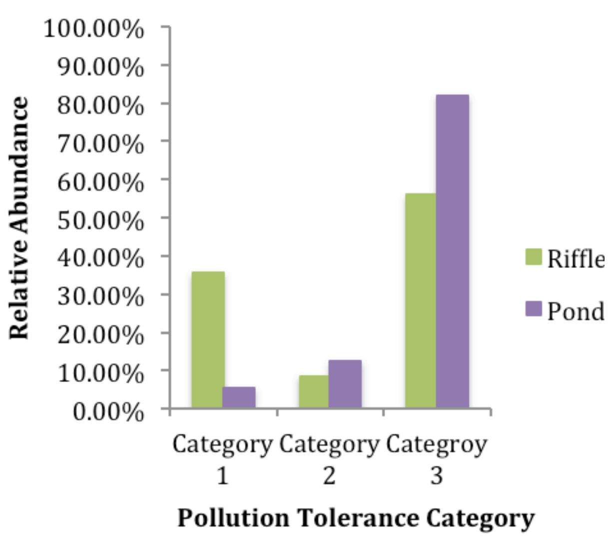

Figure 9 – Relative abundances of species in riffle and pond zones for the upstream section.

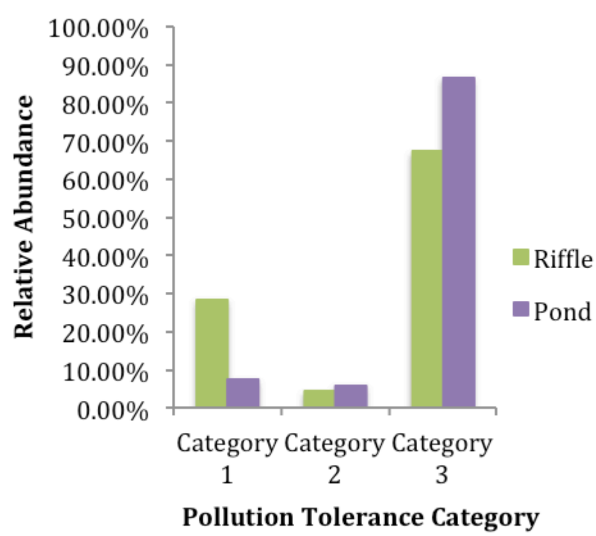

Figure 10 – Relative abundances of species in riffle and pond zones for the downstream section.

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