WASHINGTON STATE
DEPARTMENT OF
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Benthic Macroinvertebrate Study

A Cumulative Impact Assessment After Timber Harvesting in a Small Watershed

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Abstract

The benthic macroinvertebrate communities were sampled in McDonald Creek and South Fork (SF) Fulton Creek, two low order tributaries to Hood Canal in Jefferson County, Washington. The creeks were sampled from 1993 through 1996 during the fall low flow period. The study was designed to monitor cumulative effects to the benthic community in McDonald Creek before and after timber harvesting. SF Fulton Creek was sampled concurrently to provide a reference condition. Loss of 1993 data precluded comparison of pre/post harvest conditions. After timber harvesting in the McDonald Creek watershed there was a major shift in bedload. Gravel from upstream inundated the lower reach. Sections of the main channel were filled resulting in subsurface flow and a loss of favorable habitat.

Macroinvertebrates were analyzed by two methods: 1) a benthic index of biotic integrity, and 2) functional feeding groups. Neither method detected significant differences between McDonald Creek and the reference condition. Sampling the best available habitat did not describe the hydrologic impacts to the ecosystem. For determining pre-existing channel integrity, transects should be considered in mapping fluctuations in physical habitat. Additionally, sampling sites bracketing the areas of timber harvesting are necessary to fully understand impacts to the system. Since pre-harvest data were not available for analysis, results from this study should not be used to determine the effectiveness of macroinvertebrates as an impact assessment tool in the harvested watershed.

Acknowledgements

I want to thank everyone who provided technical, field, taxonomic and administrative assistance on this project; it was greatly appreciated. Specifically, I would like to thank: Rob Plotnikoff for providing counsel on sampling protocol and project review; Carolyn Lee for processing the samples; Jody White for providing the taxonomic identification and assistance with data analysis; Karol Erickson and Will Kendra for providing the final review; and Shirley Rollins for formatting and processing the final document. *Thanks*.

Introduction

McDonald Creek is a tributary to Hood Canal in Jefferson County, Washington (Figure 1). Its watershed is small, approximately 1,200 acres (2 square miles). The watershed had not been harvested for at least the last 50 years. In the early 1990s, Weyerhauser Company proposed three timber harvests with related road construction. These activities were expected to affect at least 21% of the basin area. Concern regarding effects on the anadromous fisheries prompted the Port Gamble S'Klallam Tribe, later joined by Washington Department of Ecology (Ecology) Southwest Regional Office and the Skokomish Tribe, to file a forest practices appeal.

The appeal was dropped, but in response to the concerns, Weyerhauser agreed to enter into a cooperative monitoring program for the basin. The various elements of the cooperative monitoring program were carried out by Weyerhauser, the Port Gamble S'Klallam Tribe, Skokomish Tribe, Point No Point Treaty Council, and Ecology. Further information regarding the other Cooperator studies and the forest practice activities can be found in Toal (in preparation).

The Ecology Environmental Investigations and Laboratory Services (EILS) Program was responsible for evaluating cumulative effects in the lower part of the basin by assessing channel conditions (Rashin, in preparation) and macroinvertebrate communities.

Macroinvertebrates integrate environmental conditions over time and are sensitive to sediment impacts, therefore they were chosen as one of the indicators to reflect cumulative effects of upstream forest practices. A paired watershed approach was designed for assessment purposes. McDonald Creek was sampled to reflect conditions after timber harvesting while adjacent South Fork (SF) Fulton Creek, which experienced no upstream timber harvesting during the study, provided the reference condition for comparison.

Study Objective

Macroinvertebrate communities were monitored in McDonald Creek and SF Fulton Creek during pre- and post-harvest conditions to assess cumulative effects of upstream forest practices.

Methods

Study Area

Benthic macroinvertebrate surveys were performed in McDonald Creek (T25NR2WS20) and SF Fulton Creek (T25NR3WS26) (Figure 1). Both low order streams are tributaries to Hood Canal in Jefferson County. The watersheds had similar SE aspect, 4-6 percent slope, with glacial till geology. McDonald Creek was sampled about 200 meters from entry into Hood Canal, upstream of tidal influence and the crossing of Hwy 101. SF Fulton was sampled about two miles upstream, with the upper watershed size approximating that of McDonald Creek. The riparian habitat at both sample reaches was intact, consisting of mixed coniferous and deciduous trees, shrubs and herbaceous ground cover.

Benthic Macroinvertebrates

McDonald Creek was sampled before and after timber harvesting. SF Fulton Creek had no harvest management upstream of the sample reach and was sampled concurrently to provide a reference condition.

Benthic macroinvertebrate samples were collected from riffle and pool habitats within a 150-meter stream reach. Samples were collected once per year during the low flow period (September) of 1993 through 1996 following the protocols outlined by Plotnikoff (1993 and 1994) excluding physical habitat parameters. This method is applicable for small to medium streams. The protocol calls for taking samples from the range of available habitats; e.g., habitats with varying depth and substrate.

Riffle samples were collected using a D-frame kick net (500 micron mesh) with a 1-foot wide opening set securely on the stream bottom. The 2-foot area just upstream of the net was thoroughly agitated. The 'kicking' effort at each sampling location was standardized at 1-2 minutes. All hard substrates were removed and scrubbed to dislodge and collect attached organisms; hard surfaces in the sample area that could not be removed were also scrubbed. Samples were kept separate in 1-L plastic bottles and preserved in 95% ethanol.

Pool samples were also individually collected using the D-frame net described above. However, after the kicking was initiated, the net was used to sweep the water column to collect the dislodged organisms for the 1-2 minute period.

Macroinvertebrate samples were sorted individually using dissecting scopes in the Ecology benthic laboratory. Sample material was spread evenly in a tray measuring 30cm x 36cm. An insert, divided into 30-6cm x 6cm grids, was then placed over the material with a 'cookie-cutter' effect. Macroinvertebrates were sorted from a minimum of two randomly selected 6cm x 6cm squares until a minimum of 300 organisms were found and the square was completely picked (Plotnikoff, 1994). Samples were subsequently stored in 70% ethanol.

Macroinvertebrate identification was performed using a 6x stereomicroscope following the protocol described in Plotnikoff and White (1996). Identification was performed by the author and all specimens were verified by an Ecology freshwater benthic taxonomist.

Water Chemistry and Discharge

Water column measurements were taken for pH, conductivity, and temperature, at the downstream end of the reach prior to other sampling activity. A water sample was also collected and preserved for dissolved oxygen analysis. Winkler titrations were performed within 48 hrs. Measurements were taken at approximately 10:00 a.m. Flow was measured at the downstream end of the sampling reach. Standard calibration and field methods were followed to ensure accuracy (WAS, 1992 and 1993).

Data Quality & Analysis

Labels for macroinvertebrate samples collected in 1993 for both McDonald Creek and SF Fulton Creek were destroyed in storage, therefore pre-harvest data were not available for analysis.

Analysis of pool samples was discontinued to focus project resources on the more productive riffle habitats.

Riffles were sorted and picked until 300 organisms were found and at least 2 squares had been completed. For all but one sample this required the completion of 30 squares. In 1996, Riffle 3 in McDonald Creek attained the 300 count within 15 squares. Data for this sample were subsequently extrapolated to represent the 2 square foot area. Taxonomic data were then compiled by compositing data from the 4 riffles to provide a mean annual value for each species.

The data were analyzed using a benthic index of biotic integrity (Index) to describe the biological condition (Kleindl, 1995). The Index was modified for this study by eliminating the percent planariidae and amphipoda abundance, determined not to be critical for these forested watersheds. The Index is comprised of individual metrics which respond to human impact. It acts as a yardstick to compare sites according to their relative condition (Karr et al, 1997). Table 1 lists the metrics and scoring criteria taken from Kleindl (1995) and used for this project.

To create the Index, each metric is given a score value relative to an Index reference condition. That is, a score of 5 reflects streams close to an expected reference condition, a score of 3 is given for intermediate conditions, and 1 point is given to those metrics which reflect more impacted conditions (Karr et al, 1997). These scores are then added and used to subsequently rank the streams. Possible scores for the Index ranged from 8 – 40, with 40 representing a minimally disturbed site. The individual metrics were analyzed for 1994 through 1996 using the attributes and coding parameters assigned to macroinvertebrate taxa by Wisseman (1996).

Invertebrate data were also categorized by functional feeding group. This is a common means to reflect food source availability and thus potential habitat availability. The five categories used in this analysis were scrapers (eat algae), shredders (eat leaves), collector-gatherers (eat large pieces of organic matter), collector-filterers (eat suspended fine organic particles), and predators (eat other invertebrates).

Chironomids were identified only to family level. Therefore, when analyzing the data by functional feeding group, the Chironomidae were removed since the family level does not provide enough resolution for this group.

Results and Discussion

Physical Habitat

There was a major shift in the bedload of McDonald Creek in 1995 and 1996. The reach being monitored was inundated with gravel and the stream channel shifted dramatically. Portions of the inundated reach began flowing subsurface and many habitat areas were filled. This narrowing of available habitat is likely to leave the macroinvertebrate community more vulnerable to subsequent disturbances. The riparian habitat stayed intact. This shift in channel configuration and movement of bedload did not occur in SF Fulton, the adjacent reference condition. The movement of bedload in McDonald Creek was due to timber harvesting in the upper McDonald Creek watershed and the resultant change in the systems' hydrology (Toal, personal communication). The shift in channel hydrology and substrate resulted in measurable impacts to McDonald Creek's anadromous fish population, temperature (Toal, personal communication) and the condition of the channel (Rashin, personal communication).

Macroinvertebrates

A list of species collected for McDonald Creek and SF Fulton can be found in Tables 2 and 3; this information is presented by individual riffle sample by year. The taxonomic data were analyzed using the mean value of 4 riffles (Appendix 1).

Table 4 provides the metric scores and Index values for McDonald and SF Fulton Creeks. Figure 2 graphically shows the Index. The mean and standard deviations of the individual metrics are illustrated in Appendix 2.

The benthic macroinvertebrate communities, as reflected in the Index, did not show an obvious pattern that could be attributed to forest management activities in the McDonald Creek watershed. Both creeks had an Index score of 36 in 1996, relative to the top score of 40, reflecting high habitat quality.

Because the Index did not show a difference between the two streams, a closer examination was made of the individual metrics. No significant difference between the two creeks was evident that would be attributable to the timber harvesting activities. The metrics often showed the same general response in both creeks over the years. The changes observed in the individual metrics in McDonald Creek were within the range of year to year variability in the reference creek (Appendix 2).

Functional feeding groups are represented in Appendix 3 as the percent of the total known feeding groups. There was an increase in the relative number of scrapers between 1995 and 1996 in McDonald Creek, however, since this was also seen in SF Fulton Creek, it cannot be attributed to impacts from timber harvesting.

It is also noteworthy that McDonald Creek had more than twice the number of chironomid midges than SF Fulton Creek. Though Chironomids are common in freshwater ecosystems, their numbers can increase in montane streams that are stressed (Wisseman,1996). Since Chironomids were only identified to the family level, the ecology and the significance of the density information cannot be fully understood.

Chemistry

General chemistry is tabulated and summarized in Appendix 4. Conductivity dropped by approximately 20 umhos/cm in both creeks over the last three years of the study. The average conductivity in McDonald Creek (78 umhos/cm) was about twice that found in SF Fulton Creek (37 umhos/cm). Dissolved oxygen was below the Class A standard in 1996 for both McDonald (7.2 mg/L) and SF Fulton (6.2 mg/L) Creeks. Both creeks were below the Class A pH standard of 6.5 S.U. during the study period; this most likely represents natural conditions.

Conclusions

McDonald Creek and SF Fulton Creek both had high Index scores with similar variability within the study period. Without the pre-harvest data, variability in the McDonald Creek Index scores cannot be directly linked to timber harvesting. Additionally, an analysis of functional feeding groups showed no changes that could be attributed to timber harvesting. There was, however, evidence that the physical habitat was degraded.

Possible reasons for impacts not being detected by bioassessment are:

- There was a lack of pre-timber harvest data;
- The biota were able to colonize the best available habitat in the downstream cumulative effects area;
- Sampling protocol targeted the range of the best available habitat;
- There was a lack of sampling sites upstream and downstream of the specific timber harvest areas;
- The Index was not sufficiently sensitive to pick up the disturbance;
- The study period was not long enough to describe the cumulative impacts to the macroinvertebrate community.

Recommendations

- Pre-harvest data are an integral part of an impact study. Multi-year pre- and post- data gathering should be used to describe the system and its variability.

- When assessing impacts of forest practices, collection of samples upstream and downstream of the impacted area should be an essential part of the study design.

- To determine pre-existing channel integrity, consider establishing sampling locations on a static transect, and returning to the same transect location annually. This would assist in mapping fluctuations in physical habitat.

- Investigating species ecology would be an important aspect of interpreting the subtleties of an Index of biotic integrity.

- This study should not be used to evaluate benefits of macroinvertebrates in assessing watershed disturbances due to the lack of pre-impact data.

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Figures

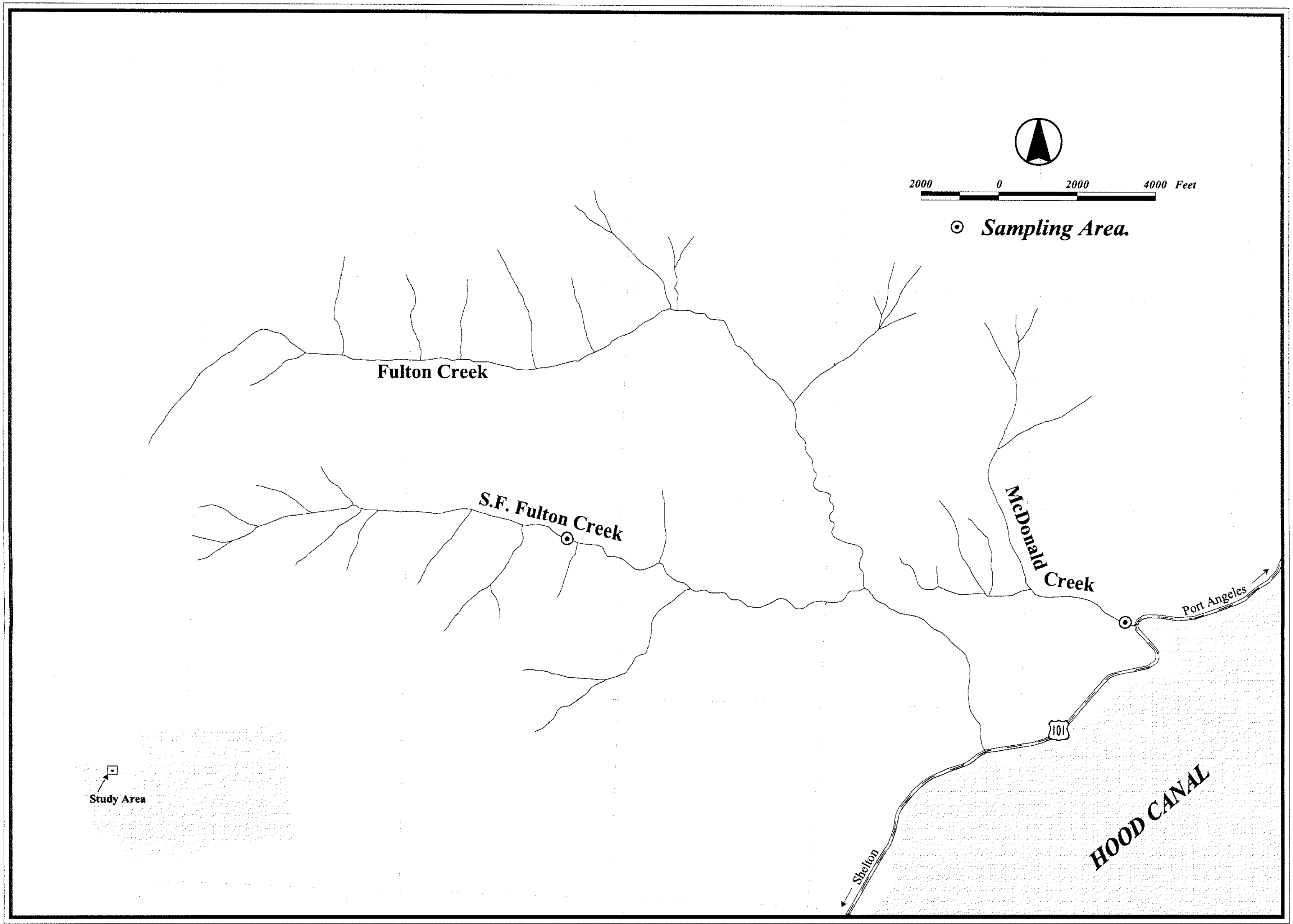


Figure 1. Sampling Areas for the McDonald Creek Macroinvertebrate Study.

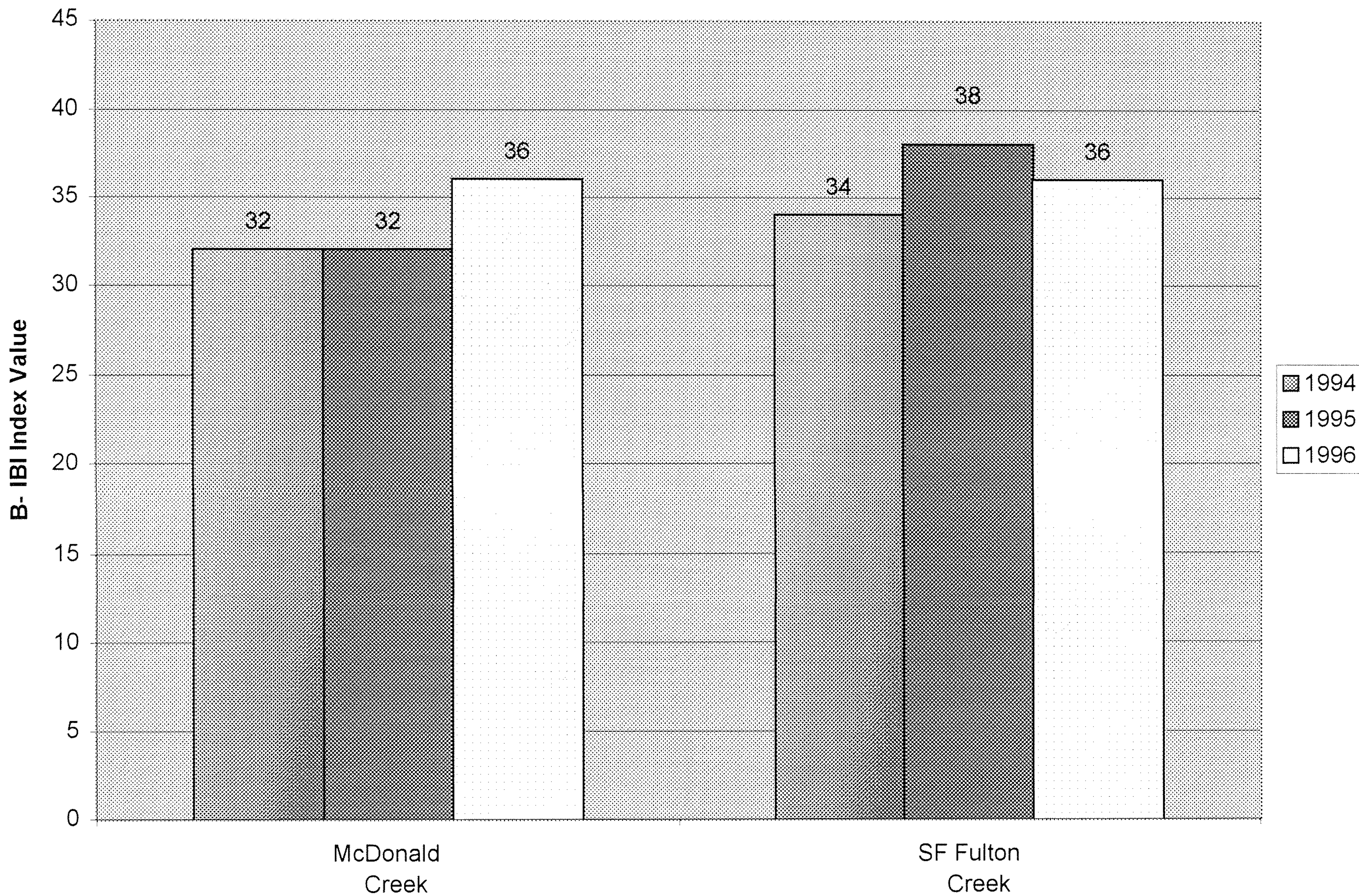


Figure 2. Benthic Index of Biotic Integrity scores for McDonald Creek and SF Fulton Creek.

Tables

Table 1. Metrics and scoring criteria used to determine the Benthic Index of Biotic Integrity for McDonald Creek and SF Fulton Creek.

Metric	Response to Human Impact	Metric Scores		
		1	3	5
Taxa Richness	**Decrease**	≤ 10.0	10 – 20	≥ 20.0
Trichoptera Richness	**Decrease**	≤ 2.0	2.0 –4.5	≥ 4.5
Plecoptera Richness	**Decrease**	≤ 3.0	3.0 – 6.0	≥ 6.0
Ephemeroptera Richness	**Decrease**	≤ 3.0	3.0 – 5.5	≥ 5.5
Intolerant Richness	**Decrease**	≤ 0.5	0.5 – 2	≥ 2
Long-Lived Richness	**Decrease**	≤ 0.5	0.5 –2	≥ 2
Predator Richness %	**Decrease**	≤ 15%	15 – 30%	≥ 30%
Tolerant Richness %	**Increase**	≥ 50%	20 – 50%	≥ 20%

Table 2. Macroinvertebrates collected in McDonald Creek; actual count by 2 sq. ft. (0.19 sq. meter) area.

McDonald Creek				1994				1995				1996			
Class	**Order**	**Family**	**Genus_species**	**R1**	**R2**	**R3**	**R4**	**R1**	**R2**	**R3**	**R4**	**R1**	**R2**	**R3**	**R4**
Insecta	Ephemeroptera	Ameletidae	Ameletus							1			27		
		Baetidae	Baetis				2								
			Baetis tricaudatus	4	7	3			11	113	23	5		86	49
			Diphetor hageni		2	1	3		2			5	29	20	
		Ephemerellidae		2	7		7								
			Ephemerella			3			21	32	127	2	56	54	8
		Heptageniidae		6	12						1				
			Cinygmula	2	1		2		5			1	2	2	
			Heptagenia			1									
			Ironodes							3				2	3
			Rithrogena							3		3	13	22	6
		Leptophlebiidae	Paraleptophlebia	4	2		5		69	22	15	4	18	18	
Insecta	Plecoptera	Capniidae											36		
		Chloroperlidae		13			1					1	4		4
			Kathroperla perdita	3	1							1	1		
			Sweltsa	2	3	2	17	2	6	16	2	43	10	26	1
		Leuctridae									2				
		Nemouridae	Nemouridae					2							
			Zapada				1								
			Zapada cinctipes			2	1		6	5	1	5	13	2	3
			Zapada frigida				1	1							
		Peltoperlidae	Yoraperla siletz						2	1				2	3
		Perlidae	Calineuria californica	1	3	1	3		16	6	1	14	12	20	2
		Pteronarcyidae	Pteronarcys			1			3						
			Pteronarcys californica							1					
Insecta	Trichoptera	Brachycentridae	Micrasema			2	1		1	2					
		Glossosomatidae	Glossosoma	1	4				23	2	2	8	6	18	3
		Hydropsychidae										37			1
			Cheumatopsyche												1
			Hydropsyche			3			13	53		1			26
			Parapsyche elsis											2	2
		Lepidostomatidae	Lepidostoma	2	2	5	5		1	3	9		33	4	
		Limnephilidae	Ecclisomyia					4	3		2				
			Hydatophylax hesperus						1						
		Rhyacophilidae	Rhyacophila			3	2		9	3		3		34	5
			Rhyacophila Betteni Group	2	7	4	2		29	10		7	3	18	2
			Rhyacophila Coloradensis Group										2		
			Rhyacophila Hyalinata Group							8	1				1
			Rhyacophila Sibirica Group		2				5	2		11	4	18	

Table 2. Macroinvertebrates collected in McDonald Creek; actual count by 2 sq. ft. (0.19 sq. meter) area.

McDonald Creek				1994				1995				1996			
Class	Order	Family	Genus_species	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
			Rhyacophila Sibirica Group - narvae								4				
		Uenoidae	Neophylax												3
Insecta	Lepidoptera		Lepidoptera			2				1					
Insecta	Coleoptera	Elmidae							1						
Insecta	Coleoptera	Elmidae	Heterlimnius	1		1									
			Narpus concolor		2										
			Zaitzevia parvula		5	2	5		1	9	6	10	20	2	1
Insecta	Diptera			1								1			
		Ceratopogonidae	Ceratopogoninae				1		3	2	2	2	3	6	
		Chironomidae	Chironomidae	22	176	296	151	47	288	83	27	172	89	600	30
		Dixidae	Dixa	5	7	12	7		6	1	2			26	1
			Meringodixa	3	2	2	2			1				2	
		Empididae	Chelifera			1			9	1					
			Clinocera						3						
		Psychodidae	Maruina			2			2	3		1		2	1
		Simuliidae	Simuliidae		4	4				18	1			2	6
		Stratiomyidae	Stratiomyidae					1							
		Tipulidae	Clinocera						3						
			Dicranota					3	1						
			Hexatoma				1	1	2	1		1	2	2	
			Tipulidae		4	3	3								
Other	Nematomorpha		Nematomorpha												1
Other	Oligochaeta		Oligochaeta	5	1		8	1	11	2	2	11	4	6	1
Other	Acari		Acari		9	4	5	1	7	7	9	4	15	14	3

Table 3. Macroinvertebrates collected in SF Fulton Creek; actual count by 2 sq ft (0.19 sq meter) riffle area.

SF Fulton Creek				1994				1995				1996			
Class	**Order**	**Family**	**Genus_species**	**R1**	**R2**	**R3**	**R4**	**R1**	**R2**	**R3**	**R4**	**R1**	**R2**	**R3**	**R4**
Insecta	Ephemeroptera	Ameletidae	Ameletus	3		5	4		1		1	2			
		Baetidae	Baetis tricaudatus	8	29	12	3		20	5		34	46	60	85
			Diphetor hageni	1		1	1								
		Ephemerellidae	Drunella doddsi		2	3	1		1	2		1		3	2
			Ephemerella	11	1	2	1		15	1	1	2	2		2
		Heptageniidae	Cinygmula		4	3	7					1		1	
			Epeorus		1	2									
			Epeorus grandis										14	1	4
			Ironodes		7					3		1			
			Rithrogena		16		1	2	3	28	8	34	28	46	47
		Leptophlebiidae	Paraleptophlebia	12	9	3	4	3	11		28	6			
Insecta	Plecoptera	Capniidae			2				2						
		Chloroperlidae		1	3		1								
			Kathroperla perdita				2	1	1	4		4	4		
			Sweltsa	1	16	5	11	51	4	49	85	10	18	8	9
		Leuctridae		2	2		1		4	3	13		2	1	
		Nemouridae	Nemouridae				1				1				
			Malenka	1			1		1						
			Podmosta								6				
			Visoka cataractae	7	9						4	2	2		1
			Zapada oregonensis grp.									4	1		1
			Zapada cinctipes	3	8		5		1	1	6	27	1		6
			Zapada frigida								2				
		Peltoperlidae	Yoraperla siletz							1	1	1		1	3
		Perlidae		5	6										
			Calineuria californica	2	5	1	3		1	6	1	7	10	4	5
		Perlodidae	Cultus			1									
		Pteronarcyidae	Pteronarcys						1	2			1		
			Pteronarcys californica		1										
Insecta	Trichoptera	Brachycentridae	Micrasema					1		1					
		Glossosomatidae	Anagapetus		1	1				1					
			Glossosoma	1											
		Hydropsychidae	Hydropsyche		8					24	2	18	32	2	12
			Parapsyche almota							1		1			
			Parapsyche elsis							1		1	2		3
		Lepidostomatidae	Lepidostoma	32	3	9	36	9	42	12	103	27	4	3	10
		Limnephilidae	Ecclisomyia	1					3						
			Hydatophylax hesperus						1			1			
			Onocosmoecus			2									

Table 3. Macroinvertebrates collected in SF Fulton Creek; actual count by 2 sq ft (0.19 sq meter) riffle area.

SF Fulton Creek				1994				1995				1996			
Class	Order	Family	Genus_species	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
		Philopotamidae	Wormaldia						1		2	7			
		Polycentropodidae	Polycentropus						1	1					
		Rhyacophilidae	Rhyacophila			1									
			Rhyacophila Brunnea Group						1	1		3			1
Insecta	Trichoptera	Rhyacophilidae	Rhyacophila Hyalinata Group						1		2				
			Rhyacophila Sibirica Group	4	4	6	4					3		1	1
Insecta	Coleoptera	Elmidae	Heterlimnius	2							3				
			Lara avara								1				
			Optioservus								2				
Insecta	Diptera										1				
		Ceratopogonidae	Ceratopogoninae					1			1				
		Chironomidae	Chironomidae	24	25		2	3	41	5	4	71	11	1	10
		Dixidae	Dixa		1						2				
		Empididae	Chelifera								1				
		Simuliidae	Simuliidae						1	1			1		
		Tipulidae	Dicranota	1			1	4	3	1	2				1
			Hexatoma			1	1				1				
Other	Turbellaria		Turbellaria	1				1		2					
Other	Hirudinea		Hirudinea		1										
Other	Oligochaeta		Oligochaeta	5	13	24	11		15	48	26	5	4	4	
Other	Acari		Acari	4	2		7		1	1		1			

Table 4. Benthic Index of Biotic Integrity metric value and score calculation.

STREAM_ID	McDonald Creek	Index Score	McDonald Creek	Index Score	McDonald Creek	Index Score	SF Fulton	Index Score	SF Fulton	Index Score	SF Fulton	Index Score
DATE	24-Sep-94		29-Sep-95		28-Sep-96		25-Sep-94		28-Sep-95		27-Sep-96	
Taxa Richness	22	**5**	23	**5**	25.25	**5**	22.5	**5**	22.5	**5**	19	**3**
Trichopter Richness	4	**3**	5.75	**5**	6.5	**5**	3.75	**3**	5.25	**5**	4.75	**5**
Plecopter Richness	4.5	**3**	4.25	**3**	5.25	**3**	7.25	**5**	6.75	**5**	6.25	**5**
Ephemeroptera Richness	5.75	**5**	4	**3**	6.5	**5**	8.5	**5**	4.25	**3**	6	**5**
Intolerant Richness	7.75	**5**	8.25	**5**	9.75	**5**	11.75	**5**	10	**5**	10.5	**5**
Long-Lived Richness	1.5	**3**	1.25	**3**	1.5	**3**	1.5	**3**	2.25	**5**	2.2	**5**
Predator Richness %	25.1	**3**	29.9	**3**	32.9	**5**	29.3	**3**	34.1	**5**	26.0	**3**
Tolerant Richness %	2.1	**5**	6.9	**5**	5.9	**5**	1.9	**5**	2.7	**5**	5.5	**5**
Total Score		**32**		**32**		**36**		**34**		**38**		**36**

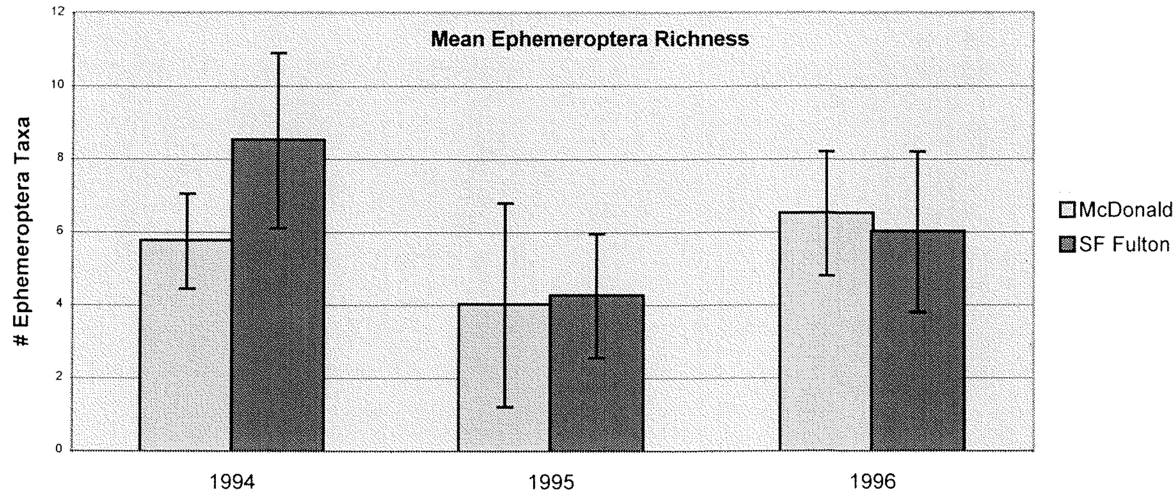
Appendices

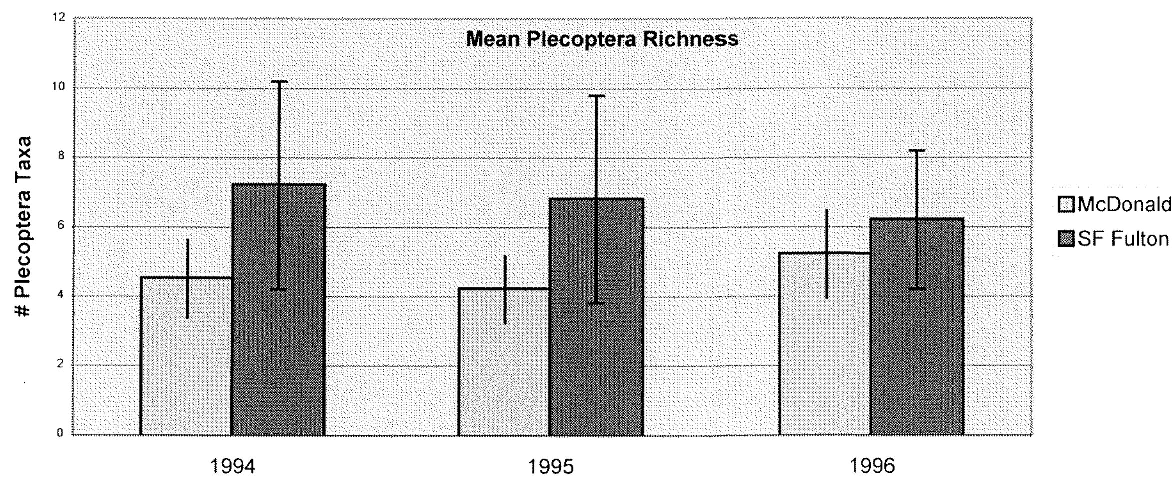
Appendix 1. Data from McDonald Creek and SF Fulton Creek reduced as an annual mean of four riffles. These data were used for analyses.

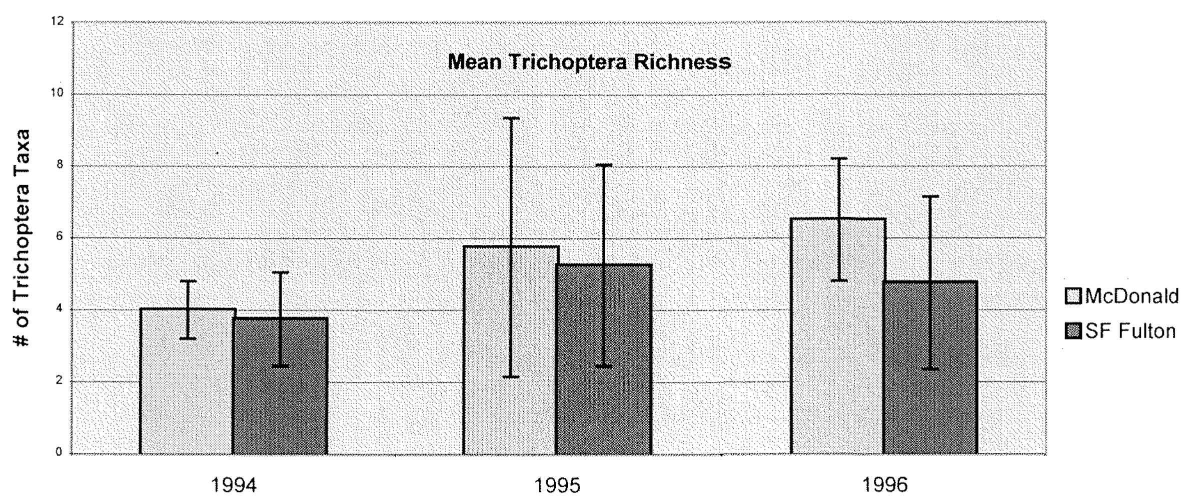
				McDonald Creek			SF Fulton Creek		
Class	Order	Family	Genus_species	1994	1995	1996	1994	1995	1996
Insecta	Ephemeroptera	Ameletidae	Ameletus		0.25	6.75	3	0.5	0.5
		Baetidae	Baetis	0.5					
			Baetis tricaudatus	3.5	36.75	35	13	6.25	56.25
			Diphetor hageni	1.5	0.5	13.5	0.75		
		Ephemerellidae	Ephemerellidae	4					
			Drunella doddsi				1.5	0.75	1.5
			Ephemerella	0.75	45	30	3.75	4.25	1.5
		Heptageniidae		4.5	0.25				
			Cinygmula	1.25	1.25	1.25	3.5		0.5
			Epeorus				0.75		
			Epeorus grandis						4.75
			Heptagenia	0.25					
			Ironodes		0.75	1.25	1.75	0.75	0.25
			Rithrogena		0.75	11	4.25	10.25	38.75
		Leptophlebiidae	Paraleptophlebia	2.75	26.5	10	7	10.5	1.5
Insecta	Plecoptera	Capniidae	Capniidae			4.5	0.5	0.5	
		Chloroperlidae		3.5		4.25	1.25		
			Kathroperla perdita	1		0.5	0.5	1.5	2
			Sweltsa	6	6.5	20	8.25	47.25	11.25
		Leuctridae			0.5		1.25	5	0.75
		Nemouridae			0.5		0.25	0.25	
			Malenka				0.5	0.25	
			Podmosta					1.5	
			Visoka cataractae				4	1	1.25
			Zapada	0.25					
			Zapada cinctipes	0.75	3	5.75	4	2	8.5
			Zapada frigida	0.25	0.25			0.5	
			Zapada oregonensis grp.						1.5
		Peltoperlidae	Yoraperla siletz		0.75	1.25		0.5	1.25
		Perlidae	Perlidae				2.75		
			Calineuria californica	2	5.75	12	2.75	2	6.5
		Perlodidae	Cultus				0.25		
		Pteronarcyidae	Pteronarcys	0.25	0.75			0.75	0.25
			Pteronarcys californica		0.25		0.25		
Insecta	Trichoptera	Brachycentridae	Micrasema	0.75	0.75			0.5	
		Glossosomatidae	Anagapetus				0.5	0.25	
			Glossosoma	1.25	6.75	8.75	0.25		
		Hydropsychidae				9.5			
			Cheumatopsyche			0.25			
			Hydropsyche	0.75	16.5	6.75	2	6.5	16
			Parapsyche almota					0.25	0.25

Appendix 1. Data from McDonald Creek and SF Fulton Creek reduced as an annual mean of four riffles. These data were used for analyses.

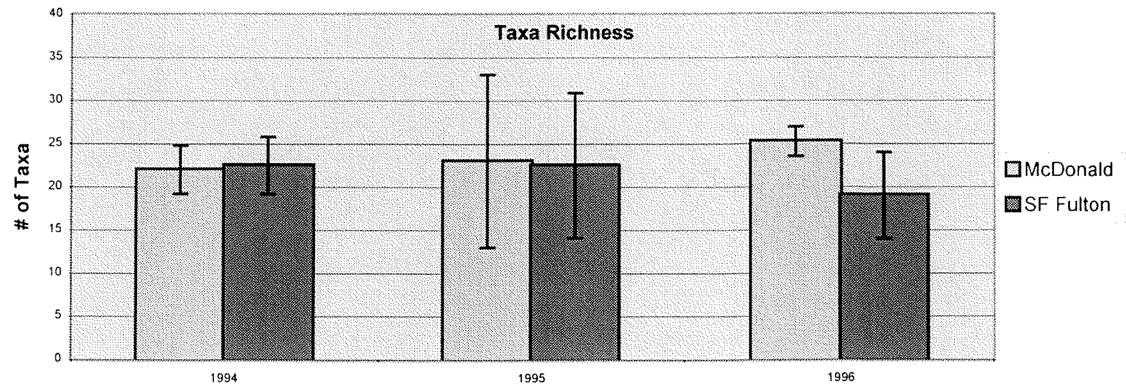
				McDonald Creek			SF Fulton Creek		
Class	Order	Family	Genus_species	1994	1995	1996	1994	1995	1996
			Parapsyche elsis			1		0.25	1.5
		Lepidostomatidae	Lepidostoma	3.5	3.25	9.25	20	41.5	11
		Limnephilidae	Ecclisomyia		2.25		0.25	0.75	
			Hydatophylax hesperus		0.25			0.25	0.25
			Onocosmoecus				0.5		
		Philopotamidae	Wormaldia					0.75	1.75
		Polycentropodidae	Polycentropus					0.5	
		Rhyacophilidae	Rhyacophila	1.25	3	10.5	0.25		
			Rhyacophila Betteni Group	3.75	9.75	7.5			
			Rhyacophila Brunnea Group					0.5	1
			Rhyacophila Coloradensis Group			0.5			
			Rhyacophila Hyalinata Group		2.25	0.25		0.75	
			Rhyacophila Sibirica Group	0.5	1.75	8.25	4.5		1.25
			Rhyacophila Sibirica Group - narvae		1				
		Uenoidae	Neophylax			0.75			
Insecta	Lepidoptera			0.5	0.25				
Insecta	Coleoptera	Elmidae			0.25				
			Heterlimnius	0.5			0.5	0.75	
			Lara avara					0.25	
			Narpus concolor	0.5					
			Optioservus					0.5	
			Zaitzevia parvula	3	4	8.25			
Insecta	Diptera			0.25		0.25		0.25	
		Ceratopogonidae	Ceratopogoninae	0.25	1.75	2.75		0.5	
		Chironomidae		161.25	111.25	222.75	12.75	13.25	23.25
		Dixidae	Dixa	7.75	2.25	6.75	0.25	0.5	
			Meringodixa	2.25	0.25	0.5			
		Empididae	Chelifera	0.25	2.5			0.25	
			Clinocera		0.75				
		Psychodidae	Maruina	0.5	1.25	1			
		Simuliidae	Simuliidae	2	4.75	2		0.5	0.25
		Stratiomyidae	Stratiomyidae		0.25				
		Tipulidae		2.5					
			Clinocera		0.75				
			Dicranota		1		0.5	2.5	0.25
			Hexatoma	0.25	1	1.25	0.5	0.25	
Other	Turbellaria						0.25	0.75	
	Hirudinea						0.25		
	Nematomorpha					0.25			
	Oligochaeta			3.5	4	5.5	13.25	22.25	3.25
	Acari			4.5	6	11.25	3.25	0.5	0.25

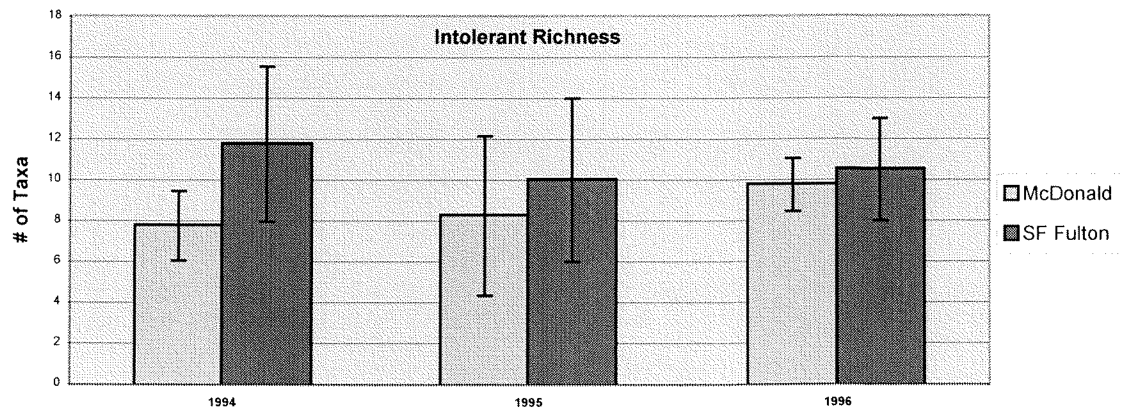


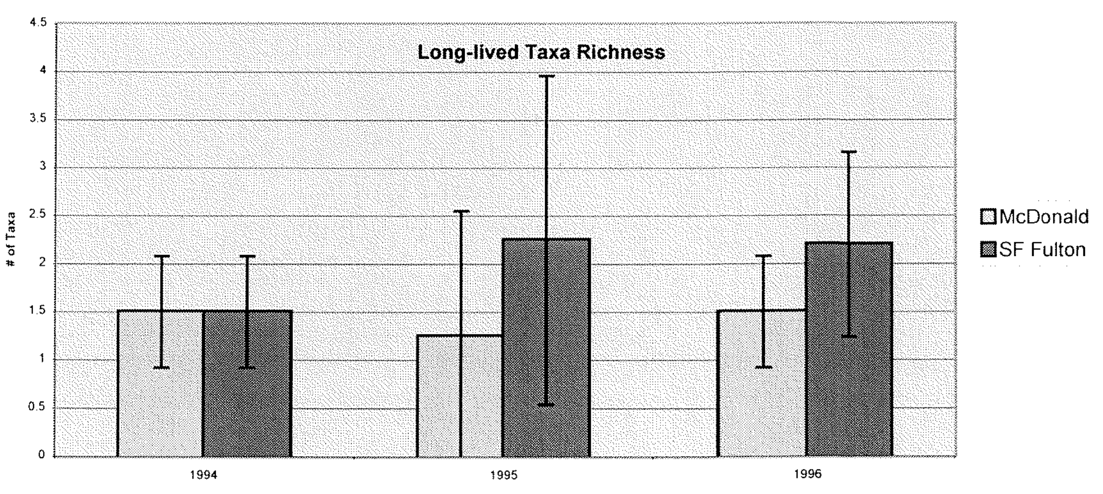




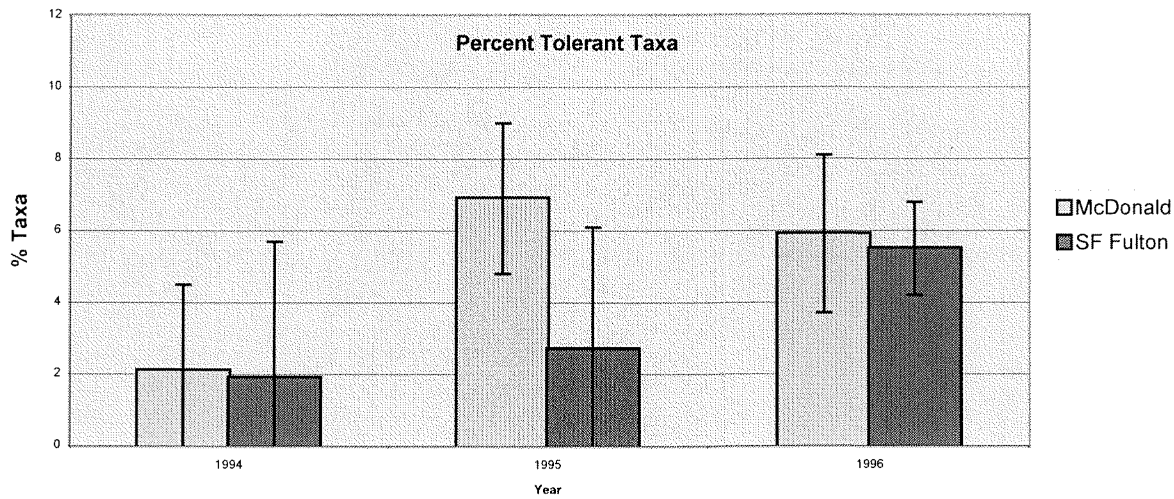
Appendix 2. Mean and standard deviation of metrics used for the Benthic Index of Biotic Integrity for McDonald Creek and SF Fulton Creek.

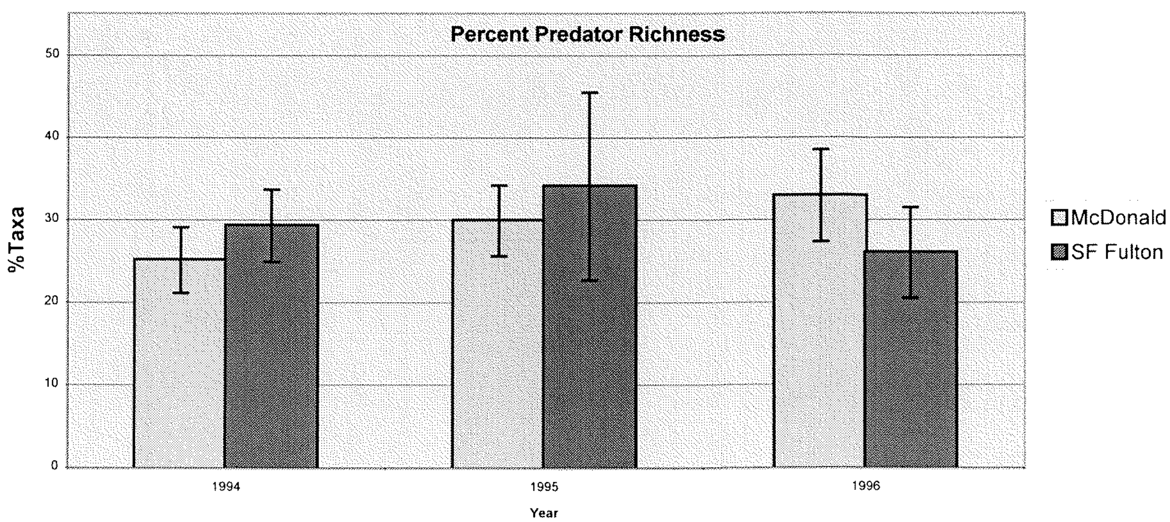




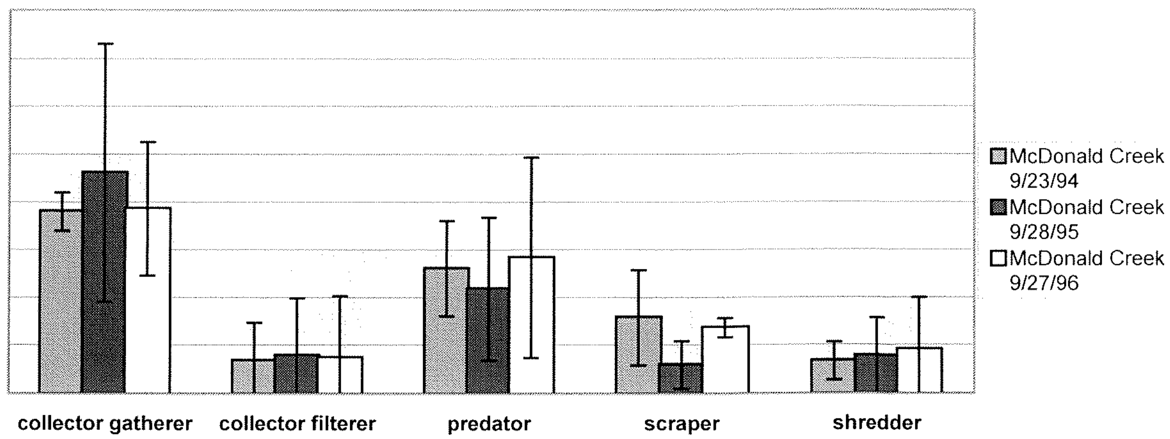


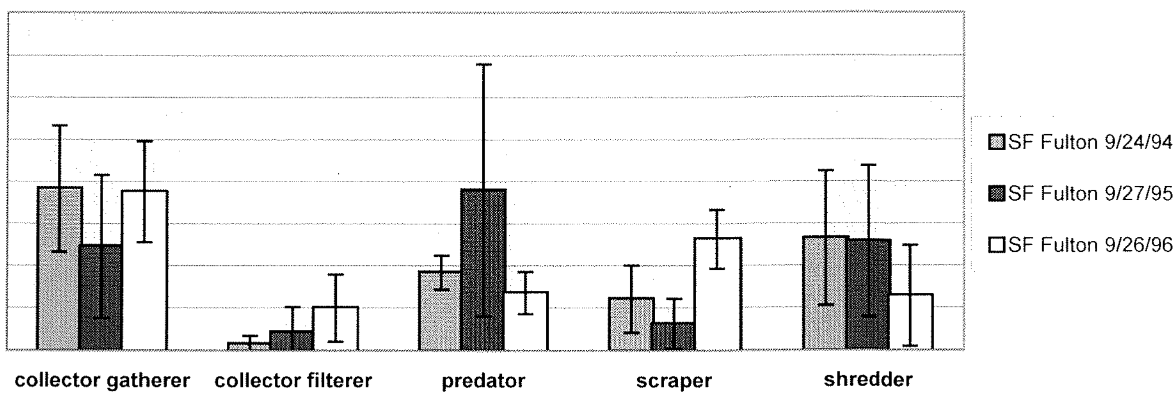
Appendix 2 (continued). Mean and standard deviation of metrics used for the Benthic Index of Biotic Integrity for McDonald Creek and SF Fulton Creek.





Appendix 2 (continued). Mean standard deviation of metrics used for the Benthic Index of Biotic Integrity for McDonald Creek and SF Fulton Creek.





Appendix 3. Percentage of the functional feeding groups found in macroinvertebrate samples from McDonald Creek and SF Fulton Creek.

Appendix 4. McDonald Creek and SF Fulton Creek general chemistry and discharge data.

Creek	Sampling Date	Temp oC	pH S.U.	Cond umhos/cm	Dissolved Oxygen mg/L	Discharge cfs
McDonald	23-Sep-94	12.5	6.3	90	8.9	0.1
McDonald	28-Sep-95	13.4	6.8	78	10.1	0.1
McDonald	27-Sep-96	11.1	6.8	66	7.2	0.1
average		**12.3**	**6.6**	**78**	**8.7**	**0.1**
SF Fulton	24-Sep-94	12.5	6.2	45	8.8	0.3
SF Fulton	27-Sep-95	11.6	6.5	38	10.1	6.9
SF Fulton	26-Sep-96	8.5	6.4	29	6.2	0.6
average		**10.9**	**6.4**	**37**	**8.4**	**2.6**