Water quality and aquatic biodiversity as assessed by macroinvertebrate analysis in three ecoregions of the Fundy Model Forest

by

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Summary

This report reviews three years of data collected since 1999 on the use of macroinvertebrates as indicators of water quality and aquatic biodiversity in relationship to land use in the Grand Lake, Continental Lowlands and Eastern Lowlands Ecoregions of the Fundy Model Forest located in southeastern New Brunswick, Canada. The Hilsenhoff Biological Index (HBI) was used to rate water quality. At 30%, the Eastern Lowlands Ecoregion had the largest number of sites at and below the water quality rating of fairly poor. Analysis of patterns of land use using Stepwise regression showed increasing water quality with increasing forestry activity in the Grand Lake Ecoregion. This may be attributable to increased primary production due to more sunlight reaching the stream following harvesting. The remaining two ecoregions contained insufficient data to access the effects of forestry on water quality. In the Continental Lowlands and Eastern Lowlands Ecoregions, water quality decreased with increasing agricultural. Using an approach that examined effects versus distance from the stream, forestry activity and agricultural activity were significantly correlated with water quality at a riparian distance up to 250 m parallel to the stream and up to 500 m upstream of the sampling site. In order to more effectively examine the effects of forestry on aquatic ecosystems it is recommended as a first step that ecoregions be examined for forestry activity within 250 m of the watercourse followed by an assessment of impacts due to roads.

Introduction

In 1997, the Canadian Council of Forestry Ministers release a document entitled, “Criteria and Indicators of Sustainable Forest Management in Canada.” This document outlined a series of criteria and indicators to be used to in evaluating sustainable forestry practices. Subsequently in 1998, the Fundy Model Forest (FMF) adopted this approach as a major part of Phase II of its program. Among the assessment criteria was the state or condition of soils and water in areas where forestry harvesting had occurred or was active. Macroinvertebrates were chosen as an indicator of both water quality and aquatic biodiversity as they respond to chemical and physical changes in their environment but also represent a diverse group of organisms making them ideal candidates for studies addressing aquatic biodiversity and ecological integrity.

Since the start of macroinvertebrates sampling in the FMF in 1998 (Chiasson and Williams 1999), macroinvertebrates have gained even wider acceptance as attested to by several major handbooks and guidebooks covering such topics as sampling design, quality control and data analysis and interpretation (Barbour et al. 1999, Culp and Halliwell 1999 and Stark et al. 2001). An ecoregion approach to sampling was adopted by the FMF to reduce variability due to geographically and climatic difference among sampling sites. Rapid biological assessment II was used for financial reasons as funding was not available for identification to the taxonomic level of species. At its inception, sampling sites were selected at random within each ecoregion to obtain an overall view of aquatic health within an area rather than evaluate the effect of any particular activity. However, the focus has become more narrow in the 2001 addressing two main categories of land use within the Fundy Model Forest, forestry and agriculture. Land use was evaluated for fixed distances upstream as well as extending out from and including the riparian zone.

This study can be considered a reconnaissance study as no work using macroinvertebrates had been conducted in the FMF prior to 1999. Therefore there were no apriori reference sites available and funds were insufficient to conduct a project of this scale. In light of new tolerance values for certain Families of macroinvertebrates since the start of the project in 1999, in addition to a new analysis of land use surrounding the sampling sites, all data since 1999 have been reexamined in this report.

Methods

Sampling methods remain unchanged from 1999 (Chiasson, 2000). A brief reviewed is provided for clarity. Using 1:85 000 maps provided by the Fundy Model Forest, first to fourth order watercourses were identified in each ecoregion: Grand Lake (1999), Continental Lowlands (2000) and the Eastern Lowlands (2001). Within each ecoregion 30 sites were selected at random, for a total of 90 sites distributed over the three ecoregions (Figure 1).

Grand Lake

Eastern
Lowlands

Continental
Lowlands

Figure 1. Distribution of sampling sites with each of the three ecoregions surveyed between 1999 and 2001. 30 sites per ecoregion.

In the event that a site was inaccessible, it was excluded and a new site selected. Sampling in all years commenced in mid-September and ended one month later. A total of eight kick-net samples were collected at each site, in addition to air and water temperature, pH, conductivity, oxygen, average stream width and depth. From 2000 onwards a general description of the stream banks were include and in 2001 the habitat evaluation form for stream surveys established by the New Brunswick Department of Natural Resource and Energy was used. Conductivity, temperature and oxygen were determined using YSI meters in all but the first year where LaMotte kits were used to determine oxygen. Where LaMotte kits were used a total of three oxygen readings were taken per site. A Oakion pH Testr 1 was used to determine pH. The kick-net was EPA certified and made of 500 ì mesh. Invertebrate samples were preserved in the field using 85% ethanol and organisms were identified to Family in the immediate months following field sampling.

Macroinvertebrates were identified in the laboratory to using the keys of Merrit and Cummins (1996). All eight samples from each site were first washed using a double sieve to remove organic debris (250 ∝ mesh). Before discarding the contents of the underlying sieve, it was

examined for macroinvertebrates that might have been carried with the outwash. Each individual sample once cleaned was then split using a zooplankton splitter. Eight of the resulting splits representing each original site were combined to form a composite sample. If necessary, the composite sample was subsampled to yield a minimum 300 organisms. The reason for composite sampling was financial.

Two types of indices were calculated, HBI (Hilsenhoff Biological Index) and %EPT (Ephemeroptera, Plecoptera, Trichoptera). The HBI values are based on a rating of sensitivity of each Family to the presence of pollutants but also respond to a wide range of activities that results in habitat degradation. Since there are no values available for New Brunswick, Canada, values were obtained from Stirbling et al. 1999, Barbour et al. 1999 and **Mandaville** 2001. The formula for HBI is:

$$\frac{\Sigma \text{ (Family tolerance value x number of organisms observed in the Family)}}{\text{Total number of organisms in the sample}}$$

Since tolerance values range from 1 to 10, the final value also ranges from 1 to 10. A low value indicate a greater presence of sensitive species, hence better water quality and greater biodiversity. The following ratings can be applied to give an overall assessment of water quality using HBI.

Table 1. Correspondence between HBI values and water quality (from Culp and Halliwell 1999)

HBI	Water Quality
0.0-3.75	Excellent
3.76-4.25	Very Good
4.26-5.00	Good
5.01-5.75	Fair
5.76-6.50	Fairly Poor
6.51-7.25	Poor
7.26-10.00	Very Poor

Percent EPT is calculated as:

$$\frac{\text{(Ephemeroptera + Plecoptera + Trichoptera) x 100}}{\text{Number of organisms in the sample}}$$

These three orders contains species that are extremely sensitive to habitat degradation such as siltation or activities that result in low oxygen such as eutrophication. Comparatively low values situation of activities that result in low oxygen such as eutrophication. Comparatively low values from otherwise similar streams with higher values within the same ecoregion are indicative of environmental problems.

Indexes and land base activities

To examine the effects of land use activities on HBI, the area upstream of the sampling sites was divided along both horizontal and vertical axes (Figure 2). Proceeding upstream, three segments

were delineated: 100 m, 250 m and 500 m. Extending out into the riparian zone at right angles to the water course, three buffer distances were established: 50 m, 100 m and 150 m. This yielded a 3 x 3 grid. These distances were used to evaluate the effect or effects of distance of activity on the HBI index value observed at the sampling sites. Stepwise regression was used to determine which combination of grids best explained the relationship if any between the HBI index and forestry and agricultural land use. Information on land use was obtained from the Fundy Model Forest GIS database.

Upstream

500

Left Bank 250 Right Bank

100

150 100 5 50 100 150

Sampling site

Figure 2. Layout of 3 x 3 grid of buffer zones and upstream distances for analysis of land use and HBI values. All distances in meters.

Results

Physical data

Site identification data and physical description of habitat for all three ecoregions can be found in Tables 1 to 3 of the Appendix. In certain years, particularly in 2001, drought conditions resulted in sampling in streams beyond 2nd order. Since oxygen is an important parameter for macroinvertebrates, percent oxygen saturation was compared to HBI values. No significant regressions were found in any of the ecoregions (Grand Lake, F = 0.540, P = 0.468; Continental Lowlands, F = 2.756, P = 0.100; Eastern Lowlands, F = 0.710, P = 0.406). Condition of the stream banks was variable, ranging from stable shrub and forest to agricultural fields extending to the streamside.

HBI and EPT Indexes

The values for the three ecoregions are found in Table 2. HBI values range from approximately 3 to a high of 8. The results of Table 2 are presented in Figure 3. In terms of percentage for sites

Table 2. HBI and %EPT values for all three ecoregions.

Grand Lake			Continental Lowlands			Eastern Lowlands		
SITE	HBI	%ETP	Site	HBI	%EPT	Site	HBI	%EPT
1	5.01	20.00	2	4.35	33.89	9	4.92	29.14
4	3.23	52.18	5	3.48	52.50	14	4.24	36.33
5	4.71	29.94	13	4.42	39.89	17	4.10	42.48
6	4.10	45.61	17	4.13	53.43	22	4.91	25.97
8	5.42	12.63	27	4.42	45.21	28	4.58	28.83
11	3.36	42.86	37	4.22	44.16	34	5.53	13.08
12	2.99	43.77	46	2.64	72.03	40	4.63	16.67
16	5.67	43.73	48	3.82	39.34	81	5.17	26.90
17	2.27	19.48	49	4.97	33.81	87	6.21	3.88
22	3.42	23.55	50	5.35	18.15	94	5.76	10.99
23	3.56	26.12	55	4.49	66.56	99	3.46	41.99
24	3.22	67.10	56	4.71	31.39	116	4.25	22.25
25	3.23	53.35	60	4.78	53.88	142	4.72	30.55
26	3.31	62.86	70	5.04	29.33	154	3.88	50.00
28	3.91	27.54	71	5.10	22.07	177	5.15	17.85
32	3.57	17.07	76	4.35	29.18	211	5.38	17.39
33	3.13	47.42	80	3.78	55.73	228	5.01	28.91
34	4.04	46.22	89	4.66	32.55	234	3.34	61.77
36	8.77	86.38	95	5.05	13.66	236	3.34	61.42
37	2.74	49.17	97	5.95	1.70	237	3.37	60.73
39	4.25	28.92	98	4.58	41.11	240	5.66	10.25
43	3.71	60.91	103	5.56	13.65	249	4.61	37.42
47	3.42	30.64	104	4.48	60.25	269	4.10	42.95
50	5.17	5.07	110	4.38	34.58	270	3.90	50.61
51	5.07	55.21	127	3.82	49.85	274	4.83	31.12
52	3.16	68.44	130	4.96	39.18	297	4.82	27.57
53	3.27	65.05	136	3.71	59.61	313	3.74	59.05
54	2.72	67.89	142	4.57	43.05	327	4.95	25.68
56	3.70	28.82	144	5.08	29.53	344	5.85	6.93
61	3.37	23.89	148	4.79	42.38	354	3.87	58.60

that rated fairly poor or worst, Grand Lake had 20%, the Continental Lowlands 23% and the Eastern Lowland 30%.

HBI Index

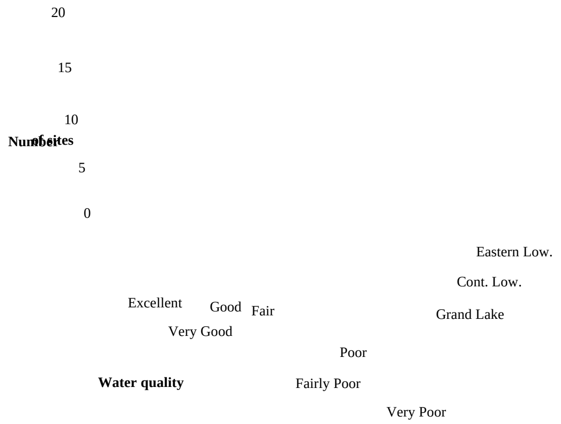

Figure 3. Water quality rated using the HBI index and Table 1. Cont. = Continental, Low. = Lowlands

Effects of forestry and agriculture

All forms of harvesting were included as forestry activity. However, roads, plantations and silviculture operations were not included in the analysis. Agriculture included any cultivation of crops other than fruit trees. The areas representing forestry and agriculture activity by ecoregions are presented in Table 3. In the Grand Lake Ecoregion, forestry activity was negatively correlated with HBI (R^2 = .40, F = 6.46, P = 0.02). However only the outer buffer and the uppermost segment upstream (3,3) were significantly correlated with HBI (Figure 4). There was no significant correlation between agriculture and HBI (F = 2.81, P = 0.11) in the Grand Lake Ecoregion. In the Continental Lowlands Ecoregion there forestry activity occurred at only one site, therefore analysis could not be conducted. Agriculture in the Continental Lowlands Ecoregion was significantly positively correlated with HBI for blocks (1,2), (1,3), (2,1) and (2,2): R^2 = 0.56 F = 2.93, P = 0.04; Figure 5.

Table 3. Forestry and agriculture activity by ecoregion. “Total” is area delineated for study in each ecoregion and not the sum of forestry and agriculture areas. Percent is in parenthesis.

Ecoregion	Area (m^2)
Grand Lake	
Forestry	183 067 (3.2)
Agriculture	1 090 052 (19.1)
Total	**5 719 299**
Continental Lowlands	
Forestry	40 956 (0.7)
Agriculture	1 454 022 (26.2)
Total	**5 550 822**
Eastern Lowlands	
Forestry	159 322 (2.9)
Agriculture	958 004 (18)
Total	**5 331 561**

For the Eastern Lowlands Ecoregion, forestry activity was too low to conduct analysis. Agriculture was found to be significantly positively correlated with HBI in blocks (1,2), (2,2), (3,3); $R^2 = 0.61$, Figure 6.

1,1 1,2 1,3

2.5 2.5 2.5

2.0 2.0 2.0

1.5 1.5 1.5

1.0 1.0 1.0

0.5 0 10 20 30 40 50 60 70 80 0.5 0 10 20 30 40 50 60 70 80 0.5 0 10 20 30 40 50 60 70 80

2,1 2,2 2,3

2.5 2.5 2.5

2.0 2.0 2.0

1.5 1.5 1.5

1.0 1.0 1.0

Ln (HBI)

0.5 0 10 20 30 40 50 60 70 80 0.5 0 10 20 30 40 50 60 70 80 0.5 0 10 20 30 40 50 60 70 80

3,1 3,2 3,3

2.5 2.5 2.5

2.0 2.0 2.0

1.5 1.5 1.5

1.0 1.0 1.0

0.5 0 10 20 30 40 50 60 70 80 0.5 0 10 20 30 40 50 60 70 80 0.5 0 10 20 30 40 50 60 70 80

Percent forestry activity

Figure 4. Mix plot of forestry activity versus HBI Index for the Grand Lake Ecoregion. Only (3,3) was found to be significant.

1,1 1,2 1,3

6 6 6
5 5 5
4 4 4
3 3 3
2 0 10 20 30 2 0 10 20 30 2 0 10 20 30

2,1 2,2 2,3

6 6 6
5 5 5
4 4 4
Ln (HBI)
3 3 3
2 0 10 20 30 2 0 10 20 30 2 0 10 20 30

3,1 3,2 3,3

6 6 6
5 5 5
4 4 4
3 3 3
2 0 10 20 30 2 0 10 20 30 2 0 10 20 30

Percent agricultural activity

Figure 5. Mix plot of agriculture activity in the Continental Lowlands Ecoregion. Only (1,2), (1,3), (2,1) and (2,2) were found to be significantly positively correlated with agriculture.

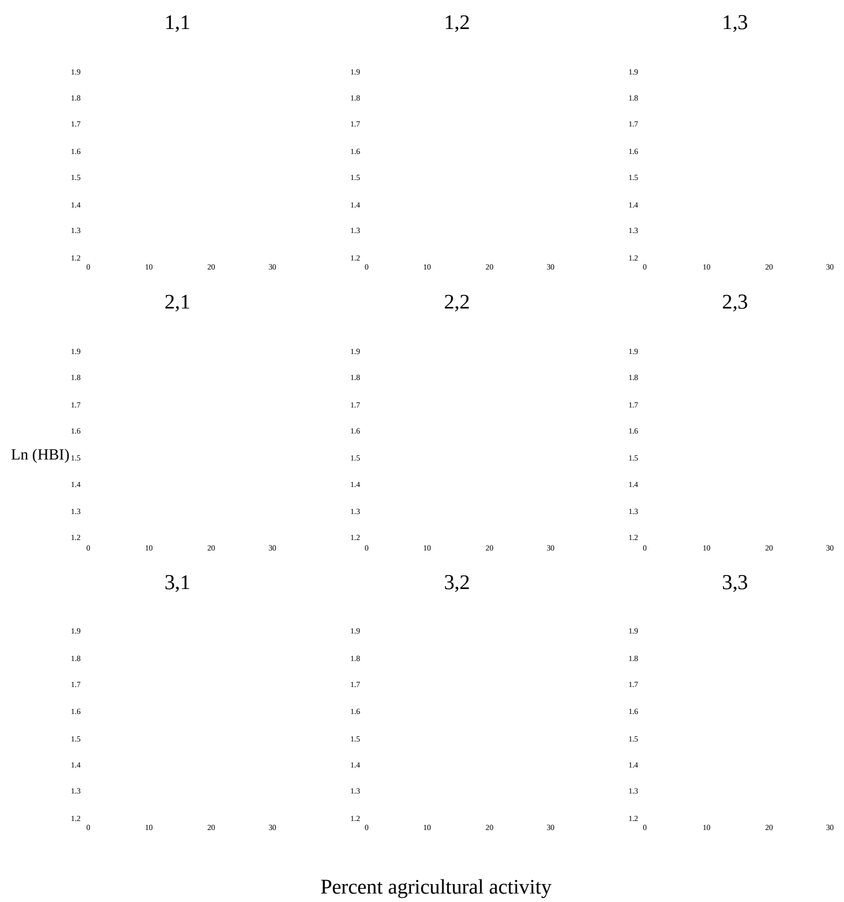

Figure 6. Mix plot of agriculture activity in the Eastern Lowlands Ecoregion. Only (1,2), (2,2), (3,3) were found to be significantly positively correlated with agriculture.

Discussion

The classification of water quality at each sites using HBI depends on the reference values used to translate index values into a rating. Since values used in this study were not specifically calibrate to this region they can only serve as guideposts. Nevertheless, macroinvertebrates are seen to responds to sources of environmental stress in similar fashion across broad thought not radically different geographical areas. By example using the same reference values for high mountain streams as for slow moving valley streams would be inappropriate. The Eastern Lowlands had the highest rating of low water quality (30%) but within this category most sites rated “Fairly poor”. Grand Lake had the highest number of “Very poor” sites. The ratings of “Fairly poor” or worst appear to be supported by statistically significant correlations between HBI values and agriculture in at least two of the ecoregions, Continental and Eastern Lowlands. However agriculture did not explain all of the variation in HBI values across sites. In addition, forestry effects could not be evaluated at the 30 sites in two ecoregions because of the small number of sites with activity within 250 m. Finally, roads were not included in this analysis.

Forestry activity was correlated with the HBI index in the Grand Lake Ecoregion but was contrary to the anticipated result as HBI values decreased with increasing forestry activity. A lower HBI value indicates a greater presence of more sensitive species. This type of outcome can be attributed to cutting in areas with very closed canopies. Harvesting opens the canopy allowing more light to reach the stream thereby increasing primary productivity and overall macroinvertebrate abundance. However, clearing too much of the shading canopy could lead to overheating due to loss of shade and potentially other problems such as bank destabilization, lack of input of leaf litter and coarse woody debris to the stream.

There was no significant correlation between percent oxygen saturation and HBI values at any of the sites. This may give a false assurance as temperatures were low due to the fall season, leading to lower levels of primary production, hence less oxygen demand.

The size of the buffer areas surrounding each stream were somewhat arbitrary in choice. A recent study on riparian zone width found no significant effects of clear cutting on water quality with a stream buffer of 60 m (Melanson 2000). In this light a 250 m outer buffer seemed appropriate for non-point sources. This does not bar drainage ditches, poor culvert installation, and toxic spills from influencing the stream from outside the boundaries used in this study but these are point sources and not currently part of the GIS database. Geographical Information Systems have been used in other studies addressing land use activity and macroinvertebrates (Richards and Host 1994). These authors using principal component analysis found the strongest correlations between course woody debris and substrate which in turn was related to macroinvertebrates.

In a study by Delong and Brusven (1998) agriculture was found to affect macroinvertebrates community structure along an agriculturally impacted stream. In this case, the macroinvertebrate community became more homogenous, its assemblage consisting of organisms able to withstand nonpoint source agricultural pollution. Using a benthic index of biological integrity (B-IBI) Fore et al. (1996) using a multivariate approach were able to distinguish disturbed streams from minimally disturbed streams. However, choice of metrics was important as they were unable to detect differences using rapid bioassessment protocol as modified by the Oregon Department of Environmental Quality. In addition principal component analysis, a multivariate approach rather than a multimetric approach, failed to detect differences.

In regards to evaluating land use effects using macroinvertebrates more research may be required to clearly delineate the best suite of metrics and whether multivariate or multimetric approaches

are best suited for nonpoint sources of habitat degradation. Incorporating numerous variables that can be measured in the field and a multitude of metrics that can be calculated is a daunting task. Clearing, the most important variables that explain the greatest variation need to be identified if possible from large datasets. This study focused on HBI and was successful in identifying effects due to agriculture. Forestry effects other than roads seemed to be restricted by a low percentage of activity with a 250 m x 500 m zone upstream of the sampling site. Since the objectives of the current study demanded a random selection of sites, further hypothesis testing regarding land use activity and area to included around the sampling site will require an alternate sampling design such as stratification of selected sites.

The following recommendations are therefore made to the Fundy Model Forest:

1) initially the bottom and top 10 sites within each ecoregion should be revisited to verify sites with the lower HBI values for suitability as reference sites and to better assess the reasons behind sites with the higher HBI values which are indicative of poor habitat quality. Reference sites would be of great value in evaluating future impacts to rivers and streams within each ecoregion. Their identification would also help to insure some form of protection. Visiting poorer sites would help identify the nature of the agriculture practices leading to the poorer ratings and confirm the conclusions of this study. It could also lead to remedial actions and better codes of practice.

2) in assessing forestry affect its may suffice to calculate within the remaining ecoregions what portion within the 250 x 500 m buffer zone has been harvested. To include year since time of harvest as an additional variable would require a large dataset but would be useful.

3) to determined if a greater buffer area should be included in future analysis or specific activities such as selective harvesting within riparian zones, test sites should be selected in advance.

Acknowledgement

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APPENDICIES

Table 1.A. Sampling sites in the Grand Lake Ecoregion. (Tr = tributary, Bk. = brook, no name = no name assigned on topographic map, usually too small)

Site	Name	Date 2000	Order	North	West
1	Tr. Ridge Bk.	Oct. 19	1	46°01.77	65°17.49
4	Ridge Bk.	Nov. 3	2	46°00.15	65°19.42
5	Tr. Patty Bk.	Oct.20	1	46°02.08	65°23.78
6	Tr. Springhill Bk.	Nov. 3	1	46°00.24	65°23.14
8	Dingley Bk.	Oct. 22	1	45°56.73	65°30.53
11	McDonalds Bk.	Oct. 20	1	46°02.50	65°28.26
12	Miller Bk.	Oct. 22	1	45°59.93	65°31.82
16	Tr. S. Br. Miller Bk.	Oct. 21	1	45°58.28	65°35.50
17	Tr. S. Br. Miller Bk.	Oct.21	2	45°59.59	65°36.29
22	Wilson Bk.	Oct. 25	1	45°55.51	65°45.87
23	N.E. Branch Long Creek	Nov. 5	1	45°54.34	65°38.64
24	Snider Bk.	Nov. 5	2	45°52.37	65°40.58
25	Chapman Bk.	Nov. 9	1	45°51.24	65°41.28
26	Lawson Bk.	Nov. 9	2	45°50.85	65°46.04
28	Tr. Salmon Creek	Oct. 28	1	45°51.05	65°49.09
32	Middle Bk.	Oct. 26	1	45°51.28	65°51.50
33	no name	Oct. 26	1	45°51.37	65°52.07
34	Colle Perry Bk.	Nov. 5	2	45°51.38	65°52.52
36	no name	Oct. 27	1	45°50.96	65°55.68
37	no name	Oct. 37	1	45°50.65	65°55.76
39	no name	Oct. 28	1	45°50.01	65°55.89
43	S.B. Mill Bk.	Nov. 5	2	45°47.39	65°53.10
47	O'Neill Bk.	Nov. 2	1	45°43.67	65°56.34
50	No name	Nov. 4	1	45°44.68	65°59.63
51	Albright Bk.	Oct. 29	2	45°42.42	65°58.69
52	MacDonalds Bk.	Oct. 29	1	45°42.36	65°59.37
53	no name	Nov. 1	1	45°42.79	66°00.26
54	no name	Nov. 1	1	45°42.84	66°00.51
56	Days Brook	Nov. 2	1	45°41.79	66°03.31
61	Carpenter Brook	Nov. 4	1	45°39.23	66°02.30

Table 1.B. Physical data for the Grand Lake Ecoregion. (Max = maximum, Avg. = average)

Site	Water °C	Oxygen (ppm) 3 readings			Conductivity (iS)	pH Max. Depth (m)	Avg. Width (m)
1	9.0	9.3	9.5	9.2	90	2.25 7.5	0.32
4	10.0	10.0	10.5	10.0	180	6.20 5.9	0.58
5	5.5	8.3	9.0	8.5	20	2.07 8.0	0.29
6	10.0	10.0	10.0	10.0	40	4.00 7.0	0.32
8	7.0	10.0	10.0	10.2	21	2.55 6.2	0.32
11	7.0	10.0	10.0	10.6	18	1.80 6.3	0.28
12	6.0	11.0	10.6	10.0	18	1.50 7.1	0.28
16	7.0	11.3	11.8	12.4	21	1.17 6.9	0.34
17	7.5	10.0	10.0	10.0	20	1.54 6.2	0.29
22	7.0	10.5	10.3	10.0	16	1.88 5.9	0.30
23	4.0	12.3	12.9	12.9	20	2.50 6.0	0.21
24	5.0	13.0	13.2	13.2	44	2.00 6.5	0.22
25	2.5	13.6	13.7	13.7	120	2.25 7.0	0.19
26	3.0	14.0	14.1	14.1	21	3.00 6.0	0.12
28	5.0	12.3	12.1	11.9	34	6.50 6.5	0.26
32	8.0	13.0	11.1	11.8	23	2.35 6.4	0.36
33	7.0	11.7	11.1	11.1	24	1.05 6.4	0.12
34	7.0	12.2	12.2	12.2	23	2.00 6.0	0.16
36	8.0	11.1	10.8	10.0	30	1.25 6.6	0.21
37	8.0	10.0	10.6	10.6	25	1.20 6.5	0.22
39	5.0	11.8	12.0	11.9	27	1.35 6.4	0.17
43	6.0	12.1	12.3	12.3	33	5.00 7.0	0.54
47	9.0	10.8	10.0	10.4	50	5.00 7.0	0.29
50	6.0	10.5	10.4	10.4	21	3.00 6.0	0.28
51	7.0	11.2	11.4	11.6	60	3.00 6.5	0.32
52	6.0	11.7	11.3	11.8	60	2.80 6.7	0.14
53	8.0	10.5	10.8	10.6	70	1.75 6.7	0.20
54	10.0	10.3	10.9	10.3	50	1.20 6.5	0.11
56	8.0	11.3	11.0	11.2	60	4.00 7.0	0.22
61	9.0	9.3	9.4	9.3	30	2.00 6.0	0.22

Table 2.A. Sampling sites in Continental Lowlands Ecoregion.

Date	Site number	Water Course	Stream order	Latitude Decimal degrees	Longitude Decimal degrees
21/09/00	2	Milton Brook	2	45.8669	64.9864

21/09/00	2	Milton Brook	2	45.8665	64.9864
	5	Popple Intervale Brook	2	45.8286	65.0564
22/09/00	13	Montgomery Brook	2	45.7922	65.1689
	17	N/A	2	45.8078	65.2944
	27	N/A	2	45.7325	65.27
	37	Mill Brook	3	45.6969	65.4633
	46	N/A	2	45.6731	65.6256
11/10/00	48	Clements Brook	2	45.6592	65.6675
	49	Moosehorn Creek	3	45.6647	65.6264
2/10/00	50	Mitchell Brook	3	45.5692	65.7125
13/10/00	55	Hammond River	2	45.5756	65.5033
17/10/00	56	Ridge Brook	2	45.9831	65.3564
	60	McDermott Brook	3	45.8883	65.3614
25/09/00	70	Sally Brook	3	45.9058	65.3758
	71	Dee Brook	3	45.8953	65.3911
	76	Harrison Brook	2	45.7944	65.48
5/10/00	80	Mill Brook	3	45.7833	65.595
16/10/00	89	Harry Brook	2	45.8689	65.5483
	95	Sharpe Brook	2	45.7292	65.6686
	97	Halfway Brook	2	45.6572	65.6689
26/09/00	98	Almshouse Brook	4	45.6325	65.7094
	103	Midland Brook	3	45.6611	65.7742
	104	Bloomfield Brook	2	45.585	65.7667
12/10/00	110	Pickwauket Brook	3	45.5444	65.8733
	127	Spragg Brook	3	45.6686	65.8717
3/10/00	130	Grant Brook	2	45.6711	65.8886
29/09/00	136	First Run Brook	1	45.6119	65.9572
4/10/00	142	Salmon Creek	2	45.8083	65.8131
18/10/00	144	Lawson Brook	2	45.8444	65.7683
	148	Chapman Brook	1	45.8403	65.6736

Table 2.B. Physical data for sampling sites in Continental Lowlands Ecoregion. (Max = maximum, Avg. = average)

Date collected	Site	Name	T(°C)	pH	Conductivity (uS)	Dissolved oxygen (ppm) I	II	III	Avg. Width (m)	Max. Depth (cm)
21-Sep-00	2	Milton Brook	18	8.5	75.6	10.50	10.10	10.30	11.0	25
21-Sep-00	5	Popple Intervale Brook	16	8.2	210.5	9.00	9.00	8.80	1.5	15
22-Sep-00	13	Montgomery Brook	13	8.2	68.2	10.60	10.30	9.70	3.5	45
22-Sep-00	17	No name	13	8.2	195.5	9.69	9.52	9.44	1.0	20
5-Oct-00	27	No name	10	8.1	87.5	11.92	11.87	11.96	3.0	17
13-Oct-00	37	Mill Brook	9	8.0	155.1	12.58	12.62	12.54	2.5	23
11-Oct-00	46	No name	9	7.9	434.5	10.03	9.70	10.00	4.0	20
11-Oct-00	48	Clements Brook	8	7.7	225.4	9.94	10.47	10.07	3.0	32
2-Oct-00	49	Moosehorn Creek	14	8.4	121.9	12.42	12.43	12.15	3.5	26
2-Oct-00	50	Mitchell Brook	12	8.0	92.0	9.41	9.48	9.04	3.0	50
13-Oct-00	55	Hammond River	7	8.0	152.7	12.37	12.40	11.97	6.0	40
17-Oct-00	56	Ridge Brook	5	7.7	902.0	11.65	11.77	11.84	2.5	20
17-Oct-00	60	McDermott Brook	7	7.9	95.5	11.27	10.99	11.1	6.0	60
25-Sep-00	70	Sally Brook	10	7.9	98.9	11.20	11.24	11.16	3.0	40
25-Sep-00	71	Dee Brook	11	8.0	110.4	11.78	11.89	11.72	3.0	35
16-Oct-00	76	Harrison Brook	6	7.8	193.4	14.23	14.25	14.19	2.5	10

5-Oct-00	80 Mill Brook	10 8.2		150.6	10.83 10.92 10.94		4.0	30
16-Oct-00	89 Harry Brook	5	7.5	60.2	13.30 13.13 12.92		4.0	6
17-Oct-00	95 Sharpe Brook	5	7.9	92.4	9.38 9.14 8.81		1.5	13
26-Sep-00	97 Halfway Brook	13 7.9		124.2	10.42 10.60 10.52		3.0	15
26-Sep-00	98 Almshouse Brook	10 8.0		214.0	12.09 12.15 12.14		2.5	30
29-Sep-00	103 Midland Brook	9	7.9	170.1	14.00 13.99 13.97		4.0	39
12-Oct-00	104 Bloomfield Brook	9	7.3	73.2	12.77 12.73 12.64		3.5	32
12-Oct-00	110 Pickwauket Brook	6	7.4	68.3	13.10 13.07 13.03		4.0	14
3-Oct-00	127 Spragg Brook	13 7.9		85.6	11.77 11.67 11.60		3.0	20
3-Oct-00	130 Grant Brook	11 7.9		113.9	10.96 11.04 10.83		1.5	18
29-Sep-00	136 First Run Brook	8	8.2	87.0	13.51 13.52 13.52		1.5	6

Table 2.B. continued. Physical data for sampling sites in Continental Lowlands Ecoregion. (Max = maximum, Avg. = average)

Date Collected	Site Name	T(°C)	pH	Conductivity (uS)	Oxygen (ppm) I II II	Avg. Width (m)	Max. Depth (cm)
4-Oct-00	142 Salmon Creek	10	8.4	78.1	9.13 8.42 8.55	1.5	12
17-Oct-00	144 Lawson Brook	4	8.3	33.2	10.05 9.69 10.27	3.5	30
4-Oct-00	148 Chapman Brook 12		8.2	271.6	8.95 8.58 8.45	1.5	20

Table 2.C. Description of riparian zones at sites in the Continental Lowlands Ecoregion.

Site number	Stream name	Description: Left stream bank	Description: Right stream bank
2	Milton Brook	20m of mature trees and bush	5m mostly bush, some mature trees
5	Popple Intervale Brook	50m of mature trees	More than 100 m of mature trees
13	Montgomery Brook	15m of bush	50m of mature trees
17	No name	1.5m of bush	10m of bush
27	No name	mature trees more than 100 m	mature trees more than 100 m
37	Mill Brook	bush more than 30m	trees more than 20m
46	No name	mature trees more than 100 m	mature trees more than 100 m

48	Clements Brook	immature trees 2m, then field 100 m	immature trees 2m, then field 100 m
49	Moosehorn Creek	rocks (highway) 20m	bush more than 100 m
50	Mitchell Brook	bush 50m, then trees more than 1000m	field more than 1000m
55	Hammond River	bush 5m, then field more than 100 m	bush 5m, then field more than 100 m
56	Ridge Brook	more than 100 m of immature trees	10m of immature trees, then highway
60	McDermott Brook	5m of tall grass, then more than 100 m of mature trees	10m of tall grass, then more than 100 m of mature trees
70	Sally Brook	more than 100 m of immature trees	more than 100 m of immature trees
71	Dee Brook	more than 100 m of immature trees	more than 100 m of mature trees
76	Harrison Brook	5m immature trees, then more than 100 m field	5m immature trees, then more than 100 m field
80	Mill Brook	field 20m	field and bush 30m
89	Harry Brook	mature trees more than 100 m	mature trees 10m
95	Sharpe Brook	5m of bush, then more than 50m of cow field	3m of bush, then 50m of field
97	Halfway Brook	10m of bush, then more than 100 m of field	10m of bush, then more than 100 m of field
98	Almshouse Brook	more than 1000m of field	10m of bush, then more than 100 m of field
103	Midland Brook	cow field more than 500m	cow field more than 500m
104	Bloomfield Brook	bush 5m, then hayfield 100 m	bush 5m, then hayfield 100 m
110	Pickwauket Brook	bush 100 m	bush 100 m
127	Spragg Brook	mature trees more than 100 m	road more than 10m, then mature trees more than 100 m
130	Grant Brook	immature trees more than 100 m	mature trees more than 100 m
136	First Run Brook	mature and immature trees 20m	immature trees more than 500m
142	Salmon Creek	mature trees more than 100 m	mature trees more than 100 m
144	Lawson Brook	10m of mature trees, then dirt road	more than 100 m of mature trees
148	Chapman Brook	mature trees more than 100 m	mature trees more than 100 m

Table 3.A. Location of sites in the Eastern Lowland Ecoregion.

Date	Site number	Water Course	Stream order	Latitude Decimal degrees	Longitude Decimal degrees
25/09/01	9	McDonald's Brook	3	46.0592	65.4703
11/10/01	14	Alward Brook	2	46.0731	65.4514
11/10/01	17	Thornes Brook	3	46.0786	65.4167
4/10/01	22	Coldstream	3	46.0711	65.3622
11/10/01	28	Ridge Brook	3	46.065	65.3053
25/09/01	34	Tributary of Wilson Brook	2	46.0670	65.2250
2/10/01	40	Killam Brook	2	46.0231	65.2508
18/09/01	81	Lewis Mt. Brook	2	46.0517	65.1675
9/10/01	87	Montgomery Brook	1	46.0639	65.1125
15/10/01	94	North River	3	46.0181	65.185
2/10/01	99	Blakney Brook	2	45.9956	65.9956
3/10/01	116	Jordan Brook	3	45.9683	65.2256
3/10/01	142	Tributary of Bennett	3	45.9589	65.2981
20/09/01	154	Tributary of Bennett	1	45.9622	65.2755
3/10/01	177	Robinson Brook	3	45.9236	65.2514
4/10/01	211	Tributary of Anagance	2	45.8317	65.3264
4/10/01	228	Tributary of Anagance	2	45.8294	65.3275
24/09/01	234	Howard Brook	3	45.8886	65.2222
15/10/01	236	Anagance River	3	45.905	65.2153
15/10/01	237	Tributary of Anagance	1	45.8956	65.1489
24/09/01	240	Tributary of Anagance	2	45.9214	65.1786
2/10/01	249	O'Blenis Brook	3	45.9433	65.1536
26/09/01	269	Chapman Brook	1	45.9944	65.14
1/10/01	270	Nigus Brook	2	45.9789	65.1089
26/09/01	274	Hasty Brook	2	46.0119	65.1211
27/09/01	297	Bennister Brook	3	46.0056	65.0592
10/10/01	313	Pollett River	3	45.9725	65.0864
10/10/01	327	Tributary of Babcock	2	45.9067	65.0533
27/09/01	344	Stiles Brook	3	45.9642	65.0056
17/09/01	354	Babcock Brook	2	45.9144	65.0792

Table 3.B. Physical site description of sampling sites in the Eastern Lowlands Ecoregion.

Site number	Temperature (°C)	pH	Conductivity (uS)	Dissolved O_2 (ppm)	Max Width (m)	Avg. Depth(cm)	Max Depth (cm)
9	12.2	7.7	90	8.61	3.3	11.7	19.0
14	9.4	7.8	50	8.18	13.5	31.0	50.0
17	13.3	7.1	60	8.33	4.5	25.7	42.0
22	10.7	7.6	110	6.34	2.7	26.0	34.0
28	14.9	8.9	330	10.50	8.8	18.3	27.0
34	16.4	7.8	50	6.50	2.8	10.7	20.0
40	7.5	7.8	110	9.62	2.5	34.0	43.0
81	13.5	7.8	240	7.83	2.3	12.7	17.0
87	7.8	7.6	350	6.12	3.0	47.0	72.0
94	13.3	7.6	1010	7.86	10.9	35.7	43.0
99	8.8	8.0	520	9.53	2.7	19.3	24.0
116	10.8	8.0	>1990	9.36	3.0	14.3	19.0
142	6.8	7.8	60	9.50	3.0	16.3	21.0
154	8.1	7.9	80	10.48	1.6	9.3	14.0
177	11.3	8.5	1090	10.93	3.2	23.0	39.0
211	13.2	7.2	60	5.16	3.1	27.7	42.0
228	15.5	7.2	50	4.98	2.1	17.7	22.0
234	13.8	8.4	70	7.80	4.3	20.0	32.0
236	13.3	7.5	90	7.19	12.0	36.7	43.0
237	11.7	7.6	80	8.84	3.8	17.3	29.8
240	16.7	7.7	50	6.81	3.7	8.7	11.0
249	12.1	7.5	200	8.86	2.6	13.7	21.0
269	15.6	7.8	460	5.70	3.0	19.0	41.0
270	9.8	7.8	50	9.43	3.6	16.3	21.0
274	17.3	7.6	130	6.23	4.4	32.0	39.0
297	15.3	7.6	120	3.90	3.0	18.0	22.0
313	13.6	7.8	60	8.81	28.0	40.0	47.0
327	6.9	7.6	70	7.49	5.0	21.7	25.0
344	14.3	8.0	110	4.50	2.8	24.0	32.0
354	12.6	8.1	80	9.80	5.6	26.3	46.0

Table 3.B. continued. Physical description of the Eastern Lowlands Ecoregion.

Site number	% Bedrock	% Boulder	% Rock	% Rubble	% Gravel	% Sand	% Fines
9	0	0	10	50	5	5	30
14	0	0	5	15	30	40	10
17	0	0	10	55	10	5	20
22	0	0	40	30	10	10	10
28	0	0	15	50	25	5	5
34	0	0	10	30	30	10	20
40	0	0	5	0	20	50	25
81	0	0	5	15	65	10	5

87	0	0	0	0	10	65	25
94	0	5	30	20	10	20	15
99	0	0	10	30	30	20	10
116	0	0	5	35	30	20	10
142	0	0	5	15	30	30	20
154	0	0	5	0	40	50	5
177	0	0	5	25	20	15	35
211	0	0	0	0	0	50	50
228	0	0	0	0	0	50	50
234	0	0	30	50	5	10	5
236	0	0	5	20	30	30	15
237	0	0	65	10	0	5	5
240	0	0	0	20	30	50	0
249	0	0	10	30	10	20	30
269	0	0	5	20	40	25	10
270	0	0	25	35	25	10	5
274	0	0	30	0	20	40	10
297	0	0	5	20	35	30	10
313	20	5	10	25	30	0	10
327	10	5	45	10	15	5	10
344	0	0	20	20	10	10	40
354	0	0	50	30	15	0	5

Table 3.C. Description of riparian zone for sites in the Eastern Lowlands Ecoregion.

		Description
Site number	Stream name	Left stream bank
9	McDonald's Brook	1m alders, shrubs and grasses, >100 m immature woods
14	Alward Brook	5-10 m shrubs, alders and grasses with a few hardwood trees. > 100 m of farm field beyond
17	Thornes Brook	10-20 m shrubs, alders and grasses. > 100 m of farm field. Very new beaver dam upstream
22	Coldstream	5 m of alders, shrubs and grasses, > 100 m of mixed immature and mature trees
28	Ridge Brook	5-10 m alders, shrubs and grasses followed by steep bank with mature trees
34	Tributary of Wilson Brook	10 m alders, shrubs and grasses, > 100 m mature fir
40	Killam Brook	> 100 m immature trees, alders shrubs and grasses
81	Lewis Mt. Brook	> 100 m of mixed of shrubs, alders and grasses
87	Montgomery Brook	Vegetation cleared for 3 meters, then mix of immature and mature trees.
94	North River	5 m alders, shrubs and grasses followed by mature trees. House 70 m away
99	Blakney Brook	50 to 100 m immature trees, shrubs and grasses, then paved road
116	Jordan Brook	> 100 m immature trees, alders, grasses, few mature trees. Road crosses 100 m upstream
142	Tributary of Bennett Brook	> 100 m mostly immature trees, few mature trees
154	Tributary of Bennett Brook	30-40 m mixed mature then clear-cut. Road 100-150 m
177	Robinson Brook	70 m of 50% grasses, 50% shrubs and immature trees. Road 70 m from stream
211	Tributary of Anagance	> 100 m shrubs and grasses, a few mature trees
228	Tributary of Anagance River	> 100 m mix of alders, shrubs and grasses
234	Howard Brook	20 m mix of alders, shrubs and grasses, >100 m mature trees
236	Anagance River	> 100 m mixed mature trees
237	Tributary of Anagance River	> 100 m mostly immature, some mature trees
240	Tributary of Anagance River	>100 m mature trees, road crossing and beaver dam 50 m upstream
249	O'Blenis Brook	> 100 m mixed, immature trees, few mature trees and alders
269	Chapman Brook	> 100 m Mix of immature trees, alders, shrubs and grasses
270	Nigus Brook	50 m alders, shrubs and grasses, few trees, then neighbors lawn
274	Hasty Brook	15 m of mature trees and grasses, 15 m immature trees then highway
297	Bennister Brook	20 m of alders, shrubs and grasses, followed by immature hardwood and a few mature trees
313	Pollett River	5 m shrubs and grasses followed by immature trees, few mature trees and grasses
327	Tributary of Babcock Brook	Grass on banks, 100 m mostly mature trees. Clear-cut beyond
344	Stiles Brook	300m of brook has farmers field adjacent, alders, and immature hardwood downstream
354	Babcock Brook	1 m grass, alders and shrubs; > 100 m mature, mixed trees

Table 3.C. continued. Description of riparian zone for sites in the Eastern Lowlands Ecoregion.

		Description
Site number	Stream name	Right stream bank
9	McDonald's Brook	5- 10 m alders, shrubs and grasses followed by immature hardwood trees
14	Alward Brook	5-10 m shrubs, alders and grasses with a few hardwood trees. > 100 m of farm field beyond
17	Thornes Brook	10-20 m shrubs, alders and grasses. > 100 m of farm field. Very new beaver dam up stream
22	Coldstream	5 m of alders, shrubs and grasses, > 100 m of mixed immature and mature trees
28	Ridge Brook	30 m immature trees, alders, shrubs and grasses followed by mature trees
34	Tributary of Wilson Brook	10 m alders, shrubs and grasses followed by immature hardwood. Camp 100 m away
40	Killam Brook	> 100 m immature trees, alders shrubs and grasses
81	Lewis Mt. Brook	75 m mix of alders, shrubs and grasses. House at 75 m
87	Montgomery Brook	Vegetation cleared for 3 meters, then mix of immature and mature trees.
94	North River	150 m immature trees & alders. Hay field at 150 m. 30 m upstream field comes to stream bank.
99	Blakney Brook	150 m of immature trees, alders, shrubs and grasses, than farmers field
116	Jordan Brook	> 100 m immature trees, alders, grasses, few mature trees. Road crosses 100 m upstream
142	Tributary of Bennett Brook	50 m of mixed, mature and immature trees followed by small cleared area
154	Tributary of Bennett Brook	> 100 m of Mature trees
177	Robinson Brook	> 100 m mix of alders, shrubs and grasses
211	Tributary of Anagance	> 100 m shrubs and grasses, a few mature trees
228	Tributary of Anagance River	> 100 m mix of alders, shrubs and grasses. Train tracks along side, crosses above site
234	Howard Brook	Mix of immature trees, alders, shrubs and grasses. Highway at 300-400 m
236	Anagance River	> 100 m mixed mature trees
237	Tributary of Anagance River	> 100 m mostly mature, some immature along stream bank
240	Tributary of Anagance River	200 m mixed mature trees, road at 200 m. Road crossing and beaver dam 50m upstream
249	O'Blenis Brook	> 100 m mixed immature trees, some alders and a few mature trees
269	Chapman Brook	> 100 m Mix of immature trees, alders, shrubs and grasses
270	Nigus Brook	10m of alders, shrubs and grasses, > 100 m of hay field
274	Hasty Brook	10 m alders, shrubs and tall grasses followed by mature trees
297	Bennister Brook	20 m of alders, shrubs and grasses, followed by immature hardwood and a few mature trees
313	Pollett River	10 m tall grasses and shrubs followed by mostly mature hardwoods, some immature
327	Tributary of Babcock Brook	5 m immature trees and grasses followed by mostly mature trees
344	Stiles Brook	Alders, grasses and immature hardwood. House 100-200 m away
354	Babcock Brook	1 m grass, alders and shrubs; > 100 m mature, mixed trees