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Report Title: Water quality and biodiversity as assessed by macroinvertebrate analysis in the Grand Lake Ecoregion of the Fundy Model Forest

Author: Chiasson, A.

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Principal contact information: Département de biologie
Université de Moncton
Moncton, N.B.
E1A 3E9

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Water quality and biodiversity as assessed by macroinvertebrate analysis in the Grand Lake Ecoregion of the Fundy Model Forest

by

Dr. Alyre Chiasson
Département de biologie
Université de Moncton
Moncton, N.B.
E1A 3E9

chiassa@umoncton.ca
Tel. 506-858-4541
Fax 506-858-4541

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Summary

A total of 30 randomly selected sites were chosen in the Grand lake Ecoregion of the Fundy Model Forest for water quality and biodiversity classification using macroinvertebrates. A modified HBI index and a %EPT index indicated that 77%of the sites rated fair to excellent. According to the %EPT index alone, 57% of these sites were excellent. Potential eutrophication problems were identified at three sites using the % Chironomidae index. Comparison of indexes with land use suggested an association between low %EPT values and agricultural practices. No association was found between forestry cover and any of the indexes used in this study. High number of Pelecypodes in two streams combined with high %EPT suggested that the tolerance value for this group should be revised, at least for New Brunswick as a means of improving the modified HBI method. Increasing and better defining reference sites could ameliorate the study.

Acknowledgements

Thanks to Kevin Pugh and Ron Talyor from the Fundy Model Forest who gave of their time to provided the GIS maps for this study and extracted the land use information from the GIS system.

Introduction

In their document entitled, "Defining Sustainable Forestry Management …," the Canadian Council of Forestry Ministers cite water quality as an indicator of sustainable forestry practice. Indicators of biodiversity, be they either aquatic or terrestrial are equally highlighted in their report (CFS 1995). The Fundy Model Forest in Phase II has undertaken the process of criteria and indicators to culminate in a report on the sustainability of forestry practices in the Fundy Model Forest. As part of this initiative, the Fundy Model Forest is evaluating water quality and aquatic biodiversity using macroinvertebrates.

In recent years, macroinvertebrates have gained in popularity as a tool for assessing water quality and have become the mainstay of programs both in the United States and the United Kingdom (Resh et al. 1995 and Barbour et al. 1999). Over 44 US states currently use macroinvertebrates as a measure of biological integrity (California Fish and Game 1999). As it pertains to forestry practices, the Foothills Model Forest is in the process of developing guidelines for use of macroinvertebrates as part of a more general program of monitoring forest biodiversity. Canada still lags considerably behind the United States in the allocation of resources necessary to implement water quality monitoring programs based on macroinvertebrates, and physical and chemical analysis. In 1996, the EPA in the United States published a bibliography listing over 1900 references regarding biological assessment, methods, biocriteria and biological indicators (Stribing et al. 1996).

Protocols for macroinvertebrates, though still in evolution can be found in a number of primary documents, the most import being Barbour et al., 1999. However, general guidelines for water quality assessment can be found in Coots (1995) and more specifically for macroinvertebrates in Cuffney (1993) and Plotnikoff (1994). An excellent working example involving biological assessment of the Coast Range Ecoregion and the Yakima River Basin can be found in Merritt et al (1999). The Fundy Model Forest has already undertaken a review of existing protocols and methods and has produced a recommend series of guidelines adapted to the Fundy Model Model Forest region. (Chiasson and Williams 1999)

Recent publications dealing with macroinvertebrates have brought to light the complexity of sections of reference conditions and subsequent analysis using multimetric and multivariate approaches. (Resh et al. 1995, Hannaford 1995, Diamond et al. 1996, Ruse 1996, Reynoldson et al. 1997 and Karr and Chu 1997). These studies, underscore the importance and variability existing in selecting both reference and evaluation sites versus the geomorphic unit used to classify the study area. Regardless of this ongoing debate, macroinvertebrates have been successful in evaluating the influence of land use on habitat quality and biotic integrity in Wisconsin streams (Wang et al. 1997), in examining the effects of agriculture (Delong and Brusven 1998) and in monitoring long-term recovery from clear cut logging (Stone and Wallace 1998).

The ecological land classification unit used for this study is ecoregion. Although, recent studies have indicated that ecoregions contain sufficient heterogeneity in soils and climates to obscure more subtle differences (Karr and Chu 1977), the ecoregion unit is still used Merritt et al. (1999) and sometimes warranted due to costs. The Fundy Model Forest contains 5 ecoregions (Zelazny 1997). The Grand Lake Ecoregion was undertaken as the first study unit for evaluation of aquatic biodiversity and water quality using macroinvertebrates. Information concerning land use was extracted from the Fundy Model Forest GIS system. Such an approach has been used before by Richards (1994).

Material and methods

First, second and third order streams in the Grand Lake Ecoregion, New Brunswick, Canada were numbered by hand using the streams and rivers layer from the Fundy Model Forest GIS. Since this map lacked watercourse names, topographical maps (1:50,000) were subsequently used to identify place names and assist in finding the streams in respect to roads and identifiable landmarks. A total of 30 sites were selected based on a random selection (Figure 1). Number of sites and absence of stratification by stream order or land use were based on financial considerations. Selected sites were visited in the field and if rejected, mainly because of very low flow, were excluded from the sampling pool and another random site was selected.

Geographic coordinates in the field were determined using a Garmin Model 315 GPS. Oxygen, conductivity, temperature and maximum depth were assessed at all sampling stations. Three independent oxygen readings were taken using a LaMotte test kit. Conductivity and water temperature were measured using a YSI conductivity meter. Final choice of sites, sampling dates, maximum depth and water chemistry are presented in Table 1.

A total of 8 kick-net samples (500ì mesh) were taken in riffle areas upstream from any bridge or culvert that might be present. A 1 m^2 area immediately upstream of the net was scoured with the heel of a boot to dislodge organisms. Drift was captured in the net, transferred to mason jars and preserved in 85 % ethanol. Each sample was then split in the lab using a plankton splitter and half of each of the eight individual samples was combined to form a single composite sample. Composite sampling places some restrictions on data analysis but can effectively capture the total variance contained within the sample (Diamond et al. 1996, Chiasson 1999).

The sample was rinsed to remove large organic debris using a double sieve; the second sieve being larger than the first and placed directly below to capture any accidental overflow of invertebrates (500ì mesh). Before discarding the contents of the second sieve, it was examined for invertebrates. A target of 300 organisms was used for identification. Subsampling, when necessary was achieved using a 1296 cm^2 tray divided into 36 equally sized grids of 6 cm$^{2.}$ The composite sample was distributed across the

Figure 1. Sampling locations in Grand Lake Ecoregion

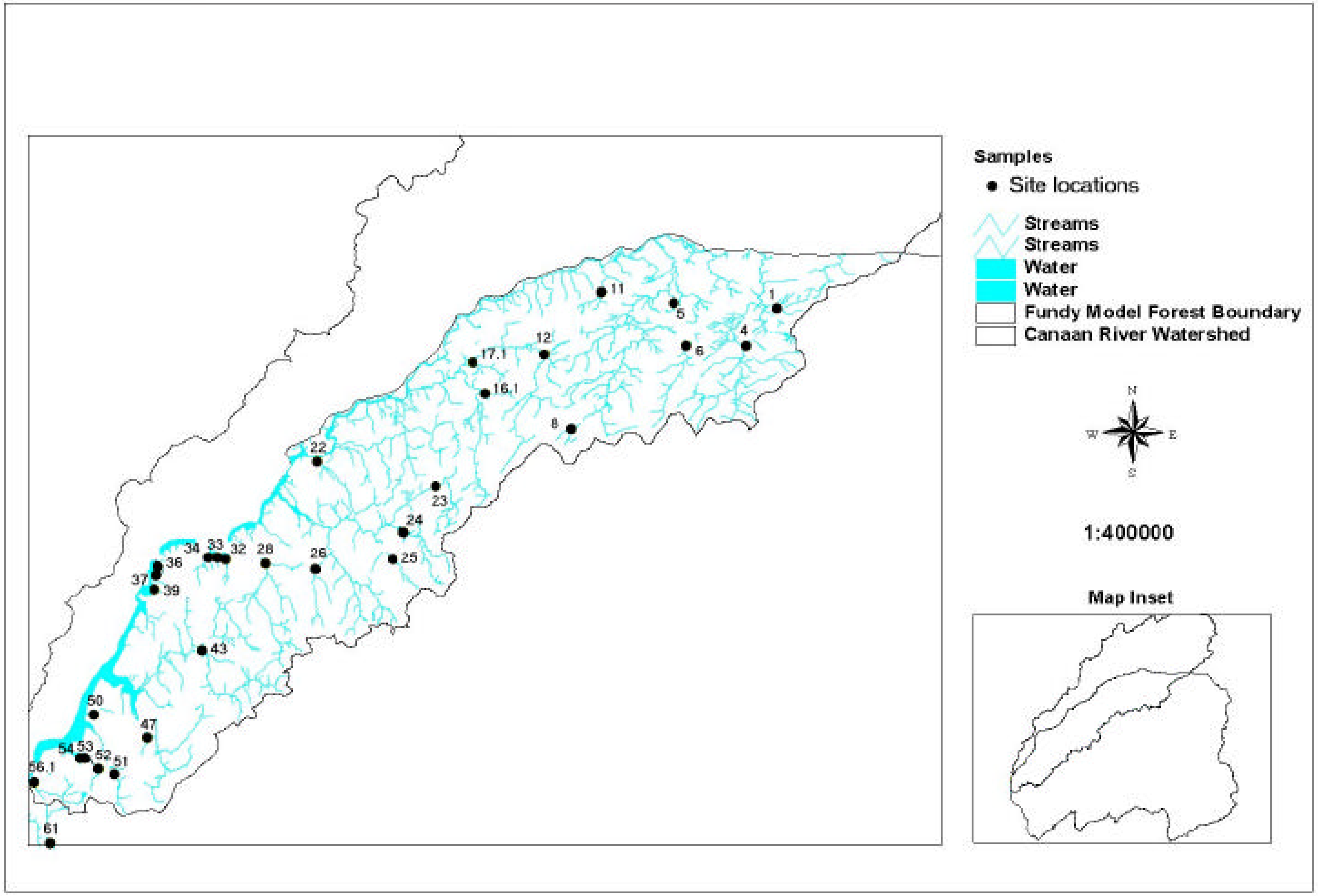


Table 1.A. Site information. All located in Grand Lake Ecoregion, New Brunswick. (Tr = tributary, Bk. = brook, no name = no name assigned on topographic map, usually too small)

Site	Name	Date 2000	Order	North	West	Width (m)
1	Tr. Ridge Bk.	Oct. 19	1	46°01.77	65°17.49	2.25
4	Ridge Bk.	Nov. 3	2	46°00.15	65°19.42	6.20
5	Tr. Patty Bk.	Oct.20	1	46°02.08	65°23.78	2.07
6	Tr. Springhill Bk.	Nov. 3	1	46°00.24	65°23.14	4.00
8	Dingley Bk.	Oct. 22	1	45°56.73	65°30.53	2.55
11	McDonalds Bk.	Oct. 20	1	46°02.50	65°28.26	1.80
12	Miller Bk.	Oct. 22	1	45°59.93	65°31.82	1.50
16.1	Tr. S. Br. Miller Bk.	Oct. 21	1	45°58.28	65°35.50	1.17
17.1	Tr. S. Br. Miller Bk.	Oct.21	2	45°59.59	65°36.29	1.54
22	Wilson Bk.	Oct. 25	1	45°55.51	65°45.87	1.88
23	N.E. Branch Long Creek	Nov. 5	1	45°54.34	65°38.64	2.50
24	Snider Bk.	Nov. 5	2	45°52.37	65°40.58	2.00
25	Chapman Bk.	Nov. 9	1	45°51.24	65°41.28	2.25
26	Lawson Bk.	Nov. 9	2	45°50.85	65°46.04	3.00
28	Tr. Salmon Creek	Oct. 28	1	45°51.05	65°49.09	6.50
32	Middle Bk.	Oct. 26	1	45°51.28	65°51.50	2.35
33	no name	Oct. 26	1	45°51.37	65°52.07	1.05
34	Colle Perry Bk.	Nov. 5	2	45°51.38	65°52.52	2.00
36	no name	Oct. 27	1	45°50.96	65°55.68	1.25
37	no name	Oct. 37	1	45°50.65	65°55.76	1.20
39	no name	Oct. 28	1	45°50.01	65°55.89	1.35
43	S.B. Mill Bk.	Nov. 5	2	45°47.39	65°53.10	5.00
47	O'Neill Bk.	Nov. 2	1	45°43.67	65°56.34	5.00
50	No name	Nov. 4	1	45°44.68	65°59.63	3.00
51	Albright Bk.	Oct. 29	2	45°42.42	65°58.69	3.00
52	MacDonalds Bk.	Oct. 29	1	45°42.36	65°59.37	2.80
53	no name	Nov. 1	1	45°42.79	66°00.26	1.75
54	no name	Nov. 1	1	45°42.84	66°00.51	1.20
56.1	Days Brook	Nov. 2	1	45°41.79	66°03.31	4.00
61	Carpenter Brook	Nov. 4	1	45°39.23	66°02.30	2.00

Table 1.B. Physical description of sites. (Cond. = conductivity, Max = maximum)

Site	Water °C	Oxygen (ppm) 3 readings			Cond. ppm	pH	Max Depth (m)
1	9.0	9.3	9.5	9.2	90	7.5	0.32
4	10.0	10.0	10.5	10.0	180	5.9	0.58
5	5.5	8.3	9.0	8.5	20	8.0	0.29
6	10.0	10.0	10.0	10.0	40	7.0	0.32
8	7.0	10.0	10.0	10.2	21	6.2	0.32
11	7.0	10.0	10.0	10.6	18	6.3	0.28
12	6.0	11.0	10.6	10.0	18	7.1	0.28
16.1	7.0	11.3	11.8	12.4	21	6.9	0.34
17.1	7.5	10.0	10.0	10.0	20	6.2	0.29
22	7.0	10.5	10.3	10.0	16	5.9	0.30
23	4.0	12.3	12.9	12.9	20	6.0	0.21
24	5.0	13.0	13.2	13.2	44	6.5	0.22
25	2.5	13.6	13.7	13.7	120	7.0	0.19
26	3.0	14.0	14.1	14.1	21	6.0	0.12
28	5.0	12.3	12.1	11.9	34	6.5	0.26
32	8.0	13.0	11.1	11.8	23	6.4	0.36
33	7.0	11.7	11.1	11.1	24	6.4	0.12
34	7.0	12.2	12.2	12.2	23	6.0	0.16
36	8.0	11.1	10.8	10.0	30	6.6	0.21
37	8.0	10.0	10.6	10.6	25	6.5	0.22
39	5.0	11.8	12.0	11.9	27	6.4	0.17
43	6.0	12.1	12.3	12.3	33	7.0	0.54
47	9.0	10.8	10.0	10.4	50	7.0	0.29
50	6.0	10.5	10.4	10.4	21	6.0	0.28
51	7.0	11.2	11.4	11.6	60	6.5	0.32
52	6.0	11.7	11.3	11.8	60	6.7	0.14
53	8.0	10.5	10.8	10.6	70	6.7	0.20
54	10.0	10.3	10.9	10.3	50	6.5	0.11
56.1	8.0	11.3	11.0	11.2	60	7.0	0.22
61	9.0	9.3	9.4	9.3	30	6.0	0.22

tray and random numbers corresponding to individual grid blocks were selected until a minimum of 300 invertebrates were subsampled. Macroinvertebrates were identified to family using a dissecting microscope and the taxonomic keys of Merritt and Cummins (1996).

Index values

Three indices were calculated: %EPT, %Chironomidae and a modified HBI (Hilsenhoff Biotic Index) (Hilsenhoff 1982). The ETP index is defined as number of Ephemeroptera, Plecoptera and Tricoptera compared to the total number of organisms. Percent Chironomidae is the total number of organisms in this family divided by the total number of organisms in the sample. Values in excess of 50% can be indicative of poor water quality (Yandora 1997) and higher concentrations in excess of 85% can signal the presence of heavy metals. The Hilsenhoff method usually requires identification to species but can be modified to family level (Bode 1990, 1991). Each family is assigned a water tolerance value from 0 to 10. Tolerance values have yet to be determined for New Brunswick. Values used were taken from Stribling et al. 1998 for Maryland streams, USA, and in some cases from Barbour et al. 1999. The formula for calculating HBI is :

$$\text{HBI} = \text{SUM}\left[\frac{(\text{Number in each family}) \times (\text{Tolerance value for each family})}{\text{total number of organisms}}\right]$$

HBI scores where classified in accordance with Roth et al. 1999, which designates scores of:

0 to 4.5 as good,
4.51 to 6.5 as faire,
6.51 to 8.5 as poor,
and 8.51 to 10.0 as very poor.

Use of the %ETP index requires reference sites, although the HBI index does give some basis of comparison. Reference sites have yet to be established in any part of New Brunswick. Instead, data from macroinvertebrates sampling conducted for another project within the same ecoregion, within the same year was used for sites if they contained salmonids (Chiasson 2000). The presence of salmonides is a good indicator of water quality. However, this limited reference sites to just three. However, %ETP was compared with the other two indexes for consistency in interpretation and comparison with land use categories can reveal important information. In accordance with other studies (Barbour 1999), the lower quartile of the reference sites were designated as poor (0 to 24.97); the second quartile, fair(> 24.97 < = 29.94); the third quartile, good (> 29.94 < = 41.06) and the last quartile excellent (> 41.06). Sampling sites were accorded a score based upon which quartile the site fell into when compared to the reference sites.

GIS was used to extract land use information from a 0.5 km^2 area located upstream from the sampling site. Factorial analysis (Systat 8) was used to determine if any relationship existed between the HBI, %Chironomidae and %ETP indices and land use within the Grand Lake ecoregion.

Results

Index values

The resulting scores are given in Table 2 and are presented graphically in Figures 2 to 4. According to the HBI index no sites rated as poor or very poor, 12 rated fair (40%) and 23 rated good (60%). The %Chironomidae index identified 3 sites as possibly suffering from eutrophication. The %EPT index, rated 7 sites as poor (23%), 4 as fair(13%), 2 as good (7%) and 17 (57%) as excellent. It is of interest to note that collectively, the poor and fair sites for %EPT accounted for 10 of the 12 sites rated as fair using HBI. Unlike the EPT index, the HBI index has no excellent category but has three categories below expected conditions (fair, poor and very poor). However, the overlap of 10 sites between HBI and EPT as being less that expected indicates, that these sites should receive further monitoring and be subject to additional investigation.

There appears to be a conflict between %EPT and HBI for sites 5 and 16.1, in that %EPT reports “good and excellent” and HBI is “Fair”. The basis for this difference is in the large number of Pelecyopda (clams) located at these sites in combination with relatively large number of Chironomidae. Pelecypoda have a tolerance value of 8 out of 10 and therefore contribute significantly to a poor rating when abundant. Such a high rating is questionable in a freshwater environment as the group is intolerant of high turbidity and shifting sands and mud (Pennak, 1989). It would appear that these sites represent an exception to the general rating of Pelecypodes as 8.

Oxygen, pH and depth

Oxygen values were well within the norms capable of supporting fish and aquatic life. There were no significant relationships between any of the index values and pH and maximum depth, with the exception of %EPT and depth (Figure 5). The %EPT index decreased significantly with depth for reasons unknown ($F = 1.17$, $n = 30$, $P < 0.05$).

Land use

Factorial analysis was used to assess whether any association existed between the three index values and land use patterns. Land use variables were obtained from the Fundy Model Forest GIS database. Variables containing less than 6 entries have to be dropped from the analysis because of restrictions stemming from the analytical procedure itself. The final set of variables is listed in Table 3. Land use values were based on a 1/2 km^2. Although, the site could have been impacted from anywhere upstream of the sampling it was felt that the size of the area chosen represented closely what an observer might conclude from actually visiting the site. The results of the analysis are presented in Figures 6 to 8. The "Factors" represent different grouping of the study variables.

Table 2 . Scoring of sites based on index values. (%CHIR = Chironomidae)

Site No.	Name	HBI	Rating	%CHIR	Eutrophic	%EPT	Rating
1	Tr. Ridge Bk.	5.01	Fair	1.518987	No	20.00	Poor
4	Ridge Bk.	3.23	Good	23.30097	No	52.18	Excellent
5	Tr. Patty Bk.	4.69	Fair	30.53892	No	29.94	Good
6	Tr. Springhill Bk.	4.10	Good	25.67568	No	45.61	Excellent
8	Dingley Bk.	5.41	Fair	18.5567	No	12.37	Poor
11	McDonalds Bk.	4.49	Good	32.36152	No	42.86	Excellent
12	Miller Bk.	3.91	Good	20.64057	No	43.77	Excellent
16.1	Tr. S. Br. Miller Bk.	4.97	Fair	18.96024	No	43.73	Excellent
17.1	Tr. S. Br. Miller Bk.	5.33	Fair	47.56554	No	19.48	Poor
22	Wilson Bk.	4.98	Fair	45.80645	No	23.55	Poor
23	N.E. Branch Long Creek	4.83	Fair	19.86301	No	26.37	Fair
24	Snider Bk.	3.57	Good	23.12704	No	67.10	Excellent
25	Chapman Bk.	3.38	Good	11.66181	No	53.35	Excellent
26	Lawson Bk.	3.24	Good	28.57143	No	62.86	Excellent
28	Tr. Salmon Creek	4.75	Fair	60	Yes	27.54	Fair
32	Middle Bk.	4.95	Fair	54.3554	Yes	17.07	Poor
33	no name	3.59	Good	28.26748	No	47.42	Excellent
34	Colle Perry Bk.	4.03	Good	35.29412	No	46.22	Excellent
36	no name	1.69	Good	6.976744	No	86.38	Excellent
37	no name	3.36	Good	33.66337	No	49.17	Excellent
39	no name	4.33	Good	48.92308	No	28.92	Fair
43	S.B. Mill Bk.	3.35	Good	31.21212	No	60.91	Excellent
47	O'Neill Bk.	4.11	Good	46.46465	No	30.64	Good
50	No name	5.80	Fair	13.4058	No	5.07	Poor
51	Albright Bk.	3.28	Good	25.76687	No	55.21	Excellent
52	MacDonalds Bk.	3.44	Good	26.24585	No	68.44	Excellent
53	no name	3.51	Good	19.03114	No	65.05	Excellent
54	no name	3.35	Good	28.09365	No	67.89	Excellent
56.1	Days Brook	4.71	Fair	61.93772	Yes	29.07	Fair
61	Carpenter Brook	4.90	Fair	30.03413	No	23.89	Poor

Figure 2. HBI index values

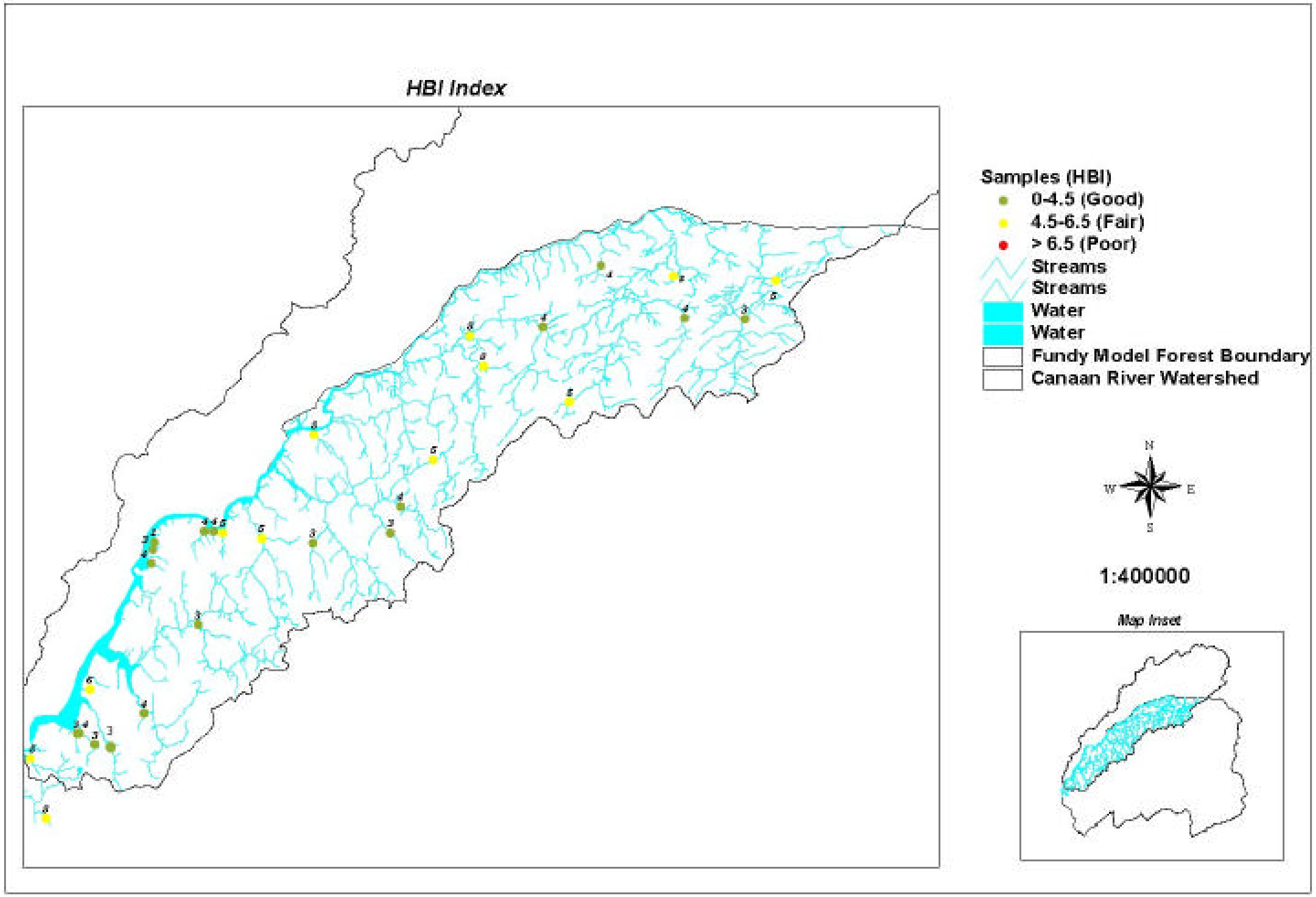


Figure 3. % Chironomidae Index

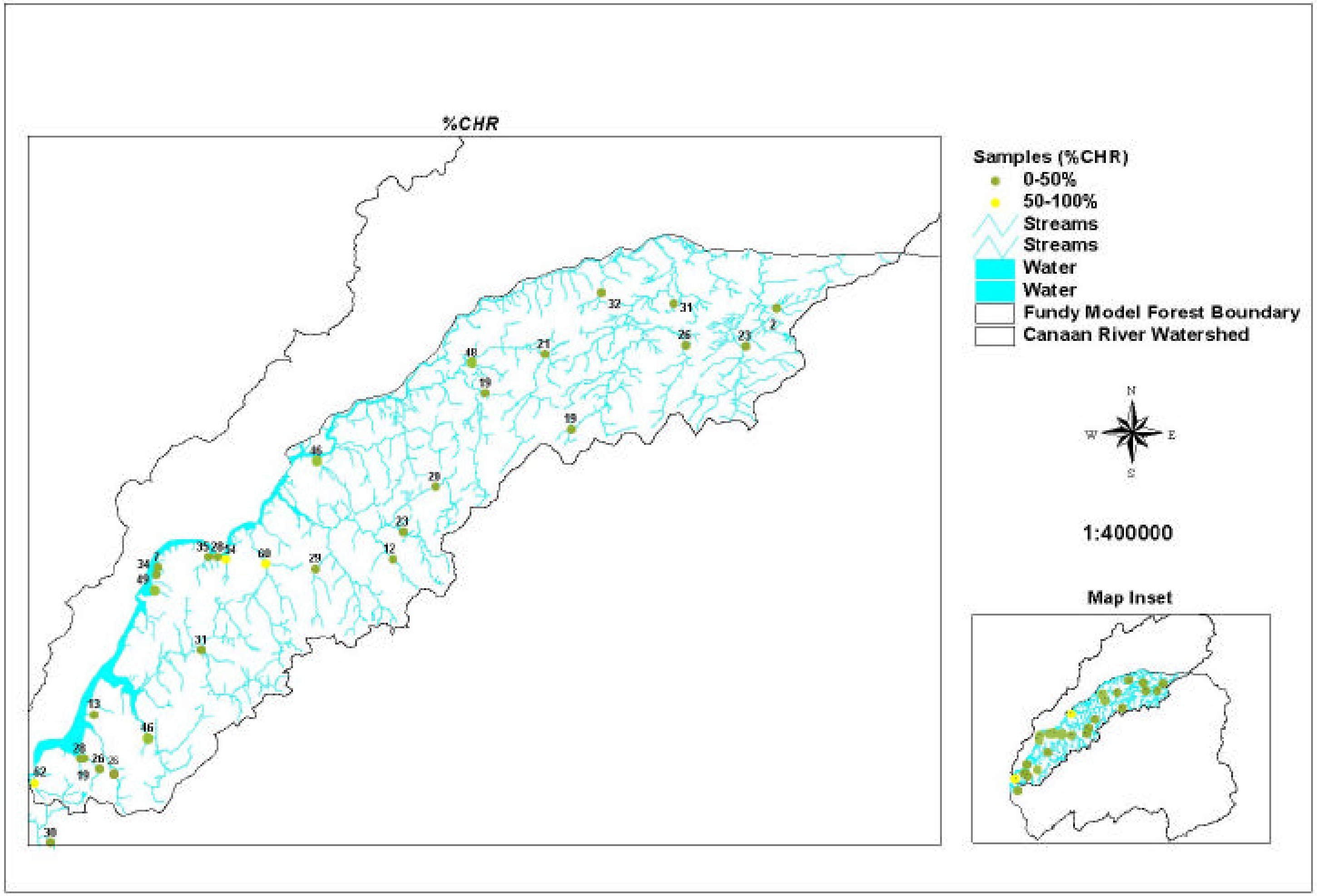


Figure 4. EPT index

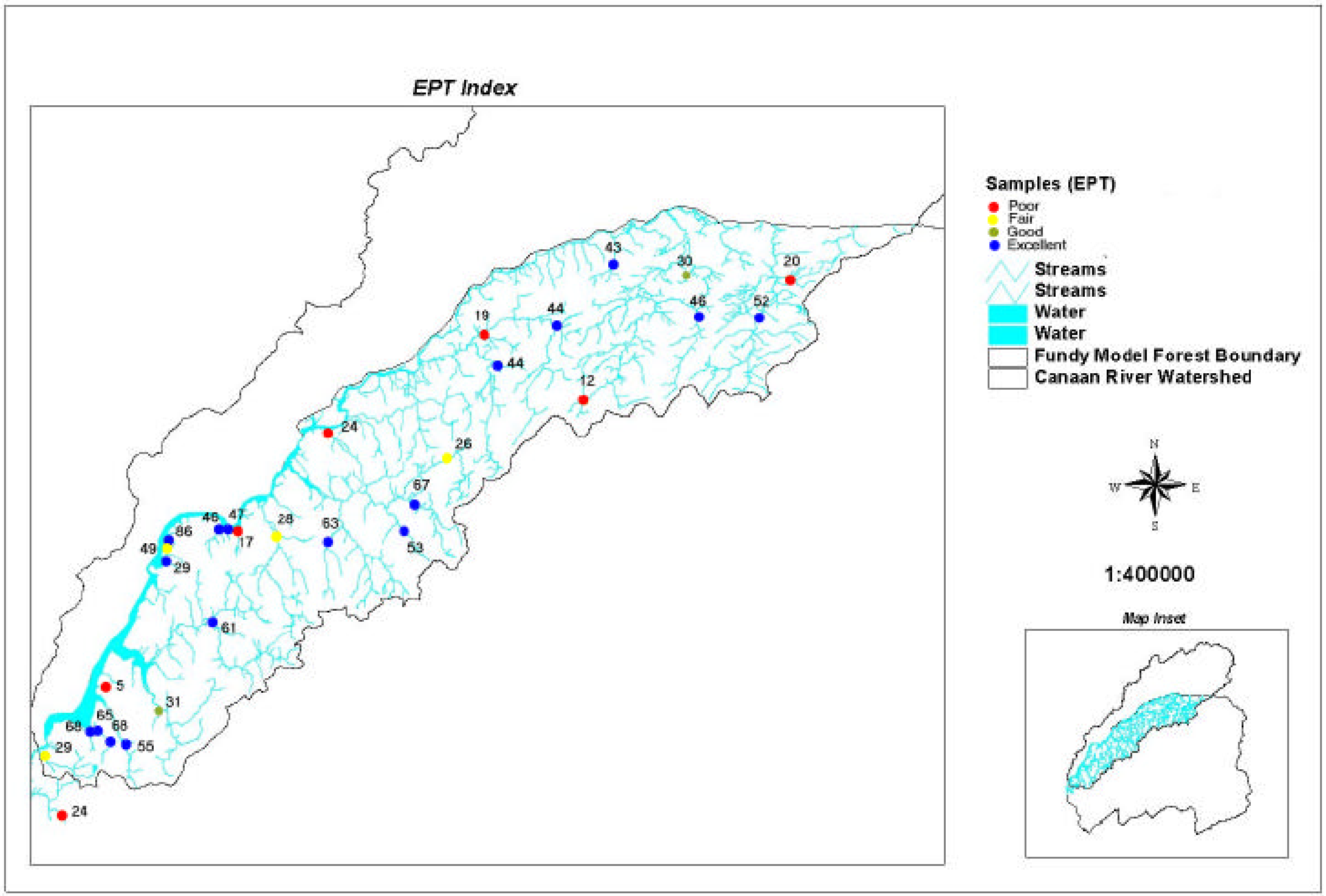


Figure 5. Index values versus pH and depth. (Chir = Chironomidae)

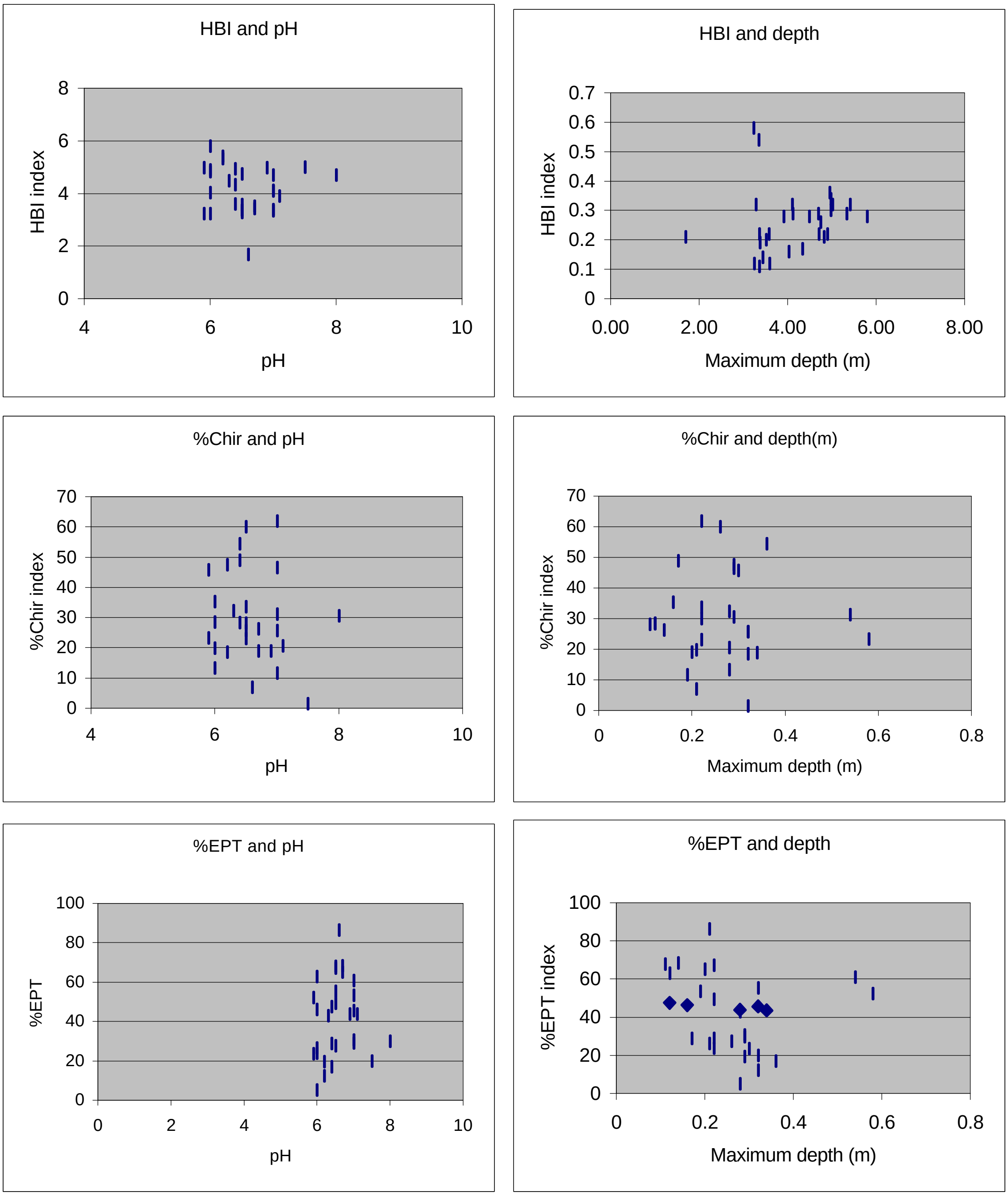


Table 3. Land use variables used in discriminate analysis.

Land use variable	Meaning
BFIH	Forest stand comprised of balsam fir and shade intolerant hardwood
CL	Cultivated farm land (commercial crops)
IHSP	Forest stand comprised primarily of shade intolerant hardwood and shade tolerant hardwood
INHW	Forest stand comprised primarily of shade intolerant hardwood
OC	Occupied - cities, towns, residential areas, etc. - minimum of 2 ha
PINE	Forest stand comprised primarily of pine
RD	Road
SPBF	Forest stand comprised primarily of spruce and balsam fir
SPIH	Forest stand comprised primarily of spruce and shade intolerant hardwood
THSP	Forest stand comprised primarily of shade tolerant hardwood and spruce
WL	Wetland

Figure 6. Plot of loading factors for Factorial Analysis with HBI and land use variables.

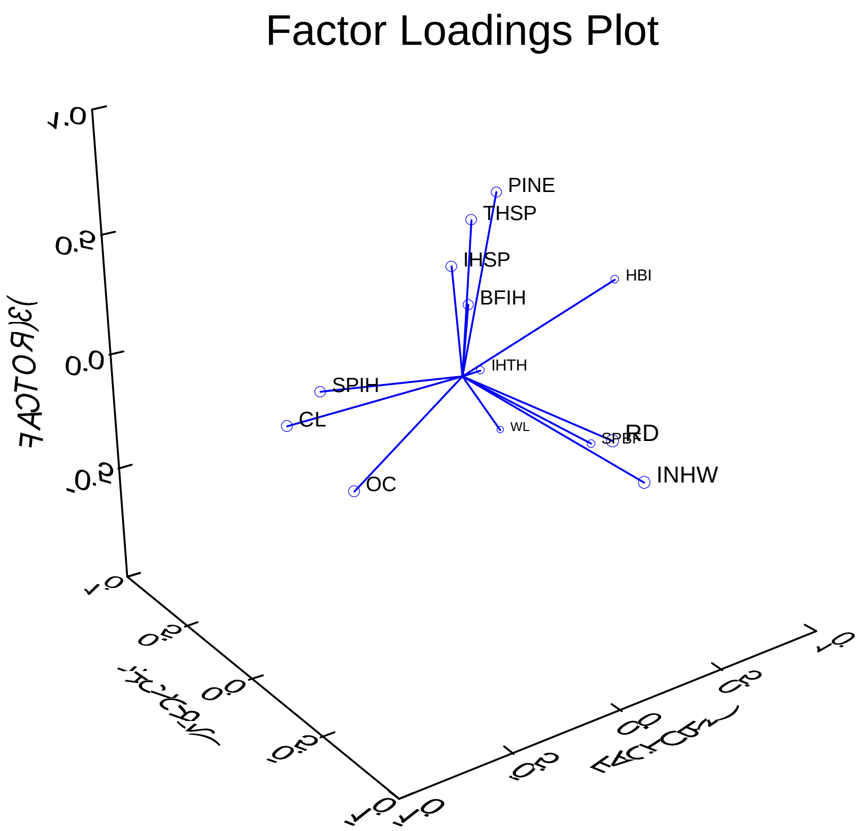


Figure 7. Plot of loading factors for Factorial Analysis with %Chironomidae and land use variables.

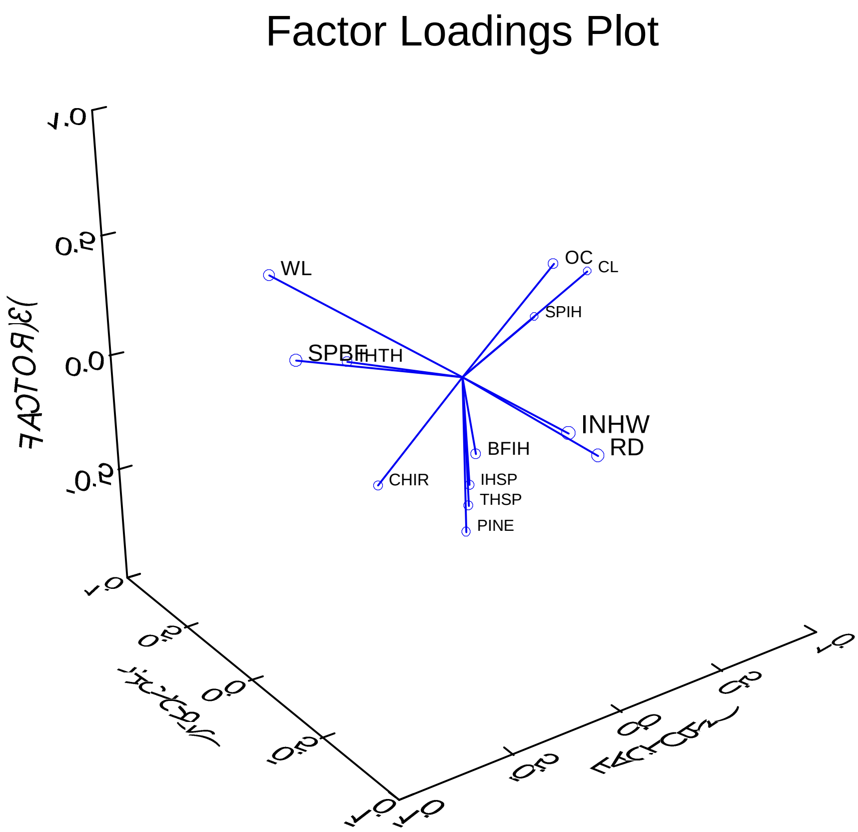
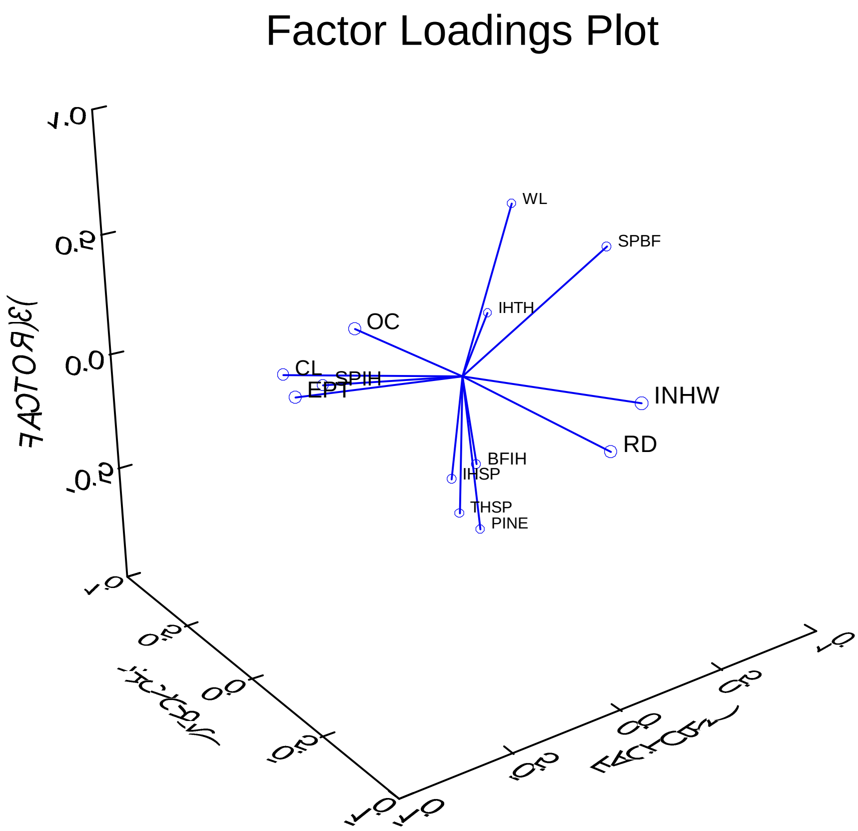


Figure 8. Plot of loading factors for Factorial analysis with HBI and land use variables.



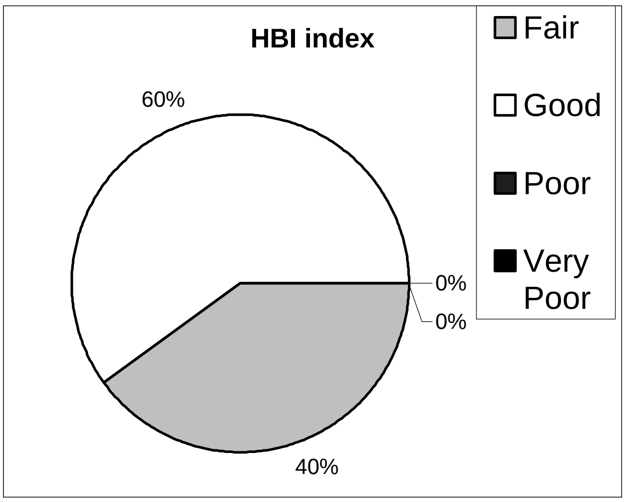
Only % EPT showed an association with other variables, CL and SPIH. The “CL” variable, which represents cultivated farmland, is of particular interest as it corresponds closely with the field notation that these sites appeared less rich in macroinvertebrate fauna than other more wooded areas.

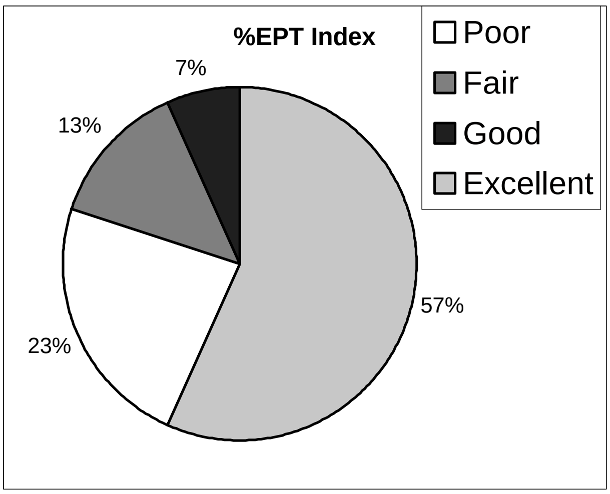
Discussion

Although the study was not designed to rely on %EPT as the main index due to financial restrictions on establishing reference sites, it has pointed to the shortcoming of using HBI when dealing with Pelecypoda in the Grand Lake Ecoregion. These two sites with abundant Pelecypoda should be revisited, perhaps with the goal of revising the tolerance value for this group in New Brunswick. The current value of 8, obtained from Stribling et al. 1998 appears too high for the Grand Lake Ecoregion in light of abundant EPT.

Based on %EPT and HBI (removing the Pelecypoda sites), 77% of sites in the study area rated fair or better. Alone, the HBI index rated 60% as good (Figure 10). According to the %EPT index 57% of the sites were excellent (Figure 10). It is recommended that the sites rated as poor using %EPT be revisited to better assess the situation.

Figure 10. HBI and EPT Index.





Factorial analysis suggests that poor ratings for %ETP may be associated with agriculture practices and not forestry. Lack of riparian zones, stream bank erosion and the various chemicals associated with agriculture can certainly eliminate more sensitive species (Delong et al. 1998).

The use of salmonids upon which to base reference sites, as done in this study is not without flaw. Whereas, their presence is certainly a good indicator, their absence may also be due to fishing pressure or unsuitability of habitat for reasons other than habitat degradation. However, habitat unsuitability should not be a problem if the ecoregion is properly classified as to climate, and geophysical features.

Sites containing the lowest %EPT and highest HBI are indicative of both low water quality and biodiversity. Water quality is taken as representing conditions existing during the life stages of the various macroinvertebrates found in the samples. Even though a spill of a hazardous substance may disappear in a stream after a relatively short period of time, the macroinvertebrate community will remain depressed during the remainder of the year resulting in a poor rating. High HBI values or low EPT values are due to loss of species and as shuch represent a reduction in aquatic biodiversity.

Reference sites are taken to represent natural conditions reflecting little to no human impact. However. they must be derived for either an ecoregion or an ecodistrict. Stribling et al. 1998 have defined these conditions as (Table 6):

Table 6. Reference site criteria (from Stribling et al. 1998)

pH 6 (if blackwater stream, pH < 6 and DOC 8 mg/L
ANC 50 ìeq/L
Dissolved O_2 4 ppm
Nitrate-N 4.2 mg/L
Urban land use 20% of catchment area
Forested land use 25% of catchment area
Remoteness rating optimal or sub-optimal
Aesthetics rating optimal or sub-optimal
Instream habitat optimal or sub-optimal
Riparian buffer width 15 m
No channelization
No point source discharges

A number of the factors in Table 6 require access to professional equipment and services. However, the importance is to define the conditions of the reference sites as closely as possible with the foreknowledge that they will establish the improvement goals for degraded sites.

Financial statement

Amount of contract	$11 363.00

Salaries	$ 8 561.83
Materials	$ 1 111.17
University administration fee	$ 1 033.00
Travel	$ 646.00
Total	$11 352.00
Balance	$ 11.00

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