Aquatic Insects in the Tomogonops and Adjacent NW Miramichi Rivers: 1996 Sampling

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ABSTRACT

Peterson, R. H., V. Zitko, K. McCarroll, and P. Harmon. 1997. Aquatic insects in the Tomogonops and adjacent NW Miramichi rivers: 1996 sampling. Can. Tech. Rep. Fish. Aquat. Sci. 2182: iii + 10 p.

Benthic invertebrates were sampled with Surber f^2 bottom samples from the Northwest Miramichi River above the confluence with the Little Tomogonops River, in the Little Tomogonops River at the mouth, and in the mixing zones of the two rivers, following the sampling strategy used in 1974-75. Mayflies (Ephemeroptera) were collected in greater numbers (ca. 44/sample) in the Tomogonops than in 1974-75 (1-2/sample). Diversity of identified taxa was still higher in samples from the Northwest Miramichi above the confluence (30) than from the Tomogonops (18) and water of largely Tomogonops origin below the confluence (21). Epeorus, Stenonema, Paraleptophlebia, planaria and oligochaetes were taxa that were commonly collected in the Northwest above the confluence and in the mixing zone, but were not collected from the Tomogonops.

RÉSUMÉ

Peterson, R. H., V. Zitko, K. McCarroll, and P. Harmon. 1997. Aquatic insects in the Tomogonops and adjacent NW Miramichi rivers: 1996 sampling. Can. Tech. Rep. Fish. Aquat. Sci. 2182: iii + 10 p.

Les invertébrés benthiques ont été échantillonnés par prélèvement au filet Surber d'échantillons d'un pi^2 de fond dans la Miramichi Nord-Ouest en amont du confluent de la Petite rivière Tomogonops, dans la Petite rivière Tomogonops à l'embouchure, et dans les zones de mélange des deux rivèrers, selon la stratégie établie en 1974-1975. Les éphémères (*Ephemeroptera*) ont été recueillies dans la Tomogonops en plus grand nombre (env. 44/échantillon) qu'en 1974-1975 (1-2/échantillon). La diversité des taxons identifiés était encore plus grande dans les échantillons de la Miramichi Nord-Ouest en amont du confluent (30) que dans la Tomogonops (18) et dans l'eau provenant surtout de la Tomogonops en aval du confluent (21). Les genres *Epeorus, Stenonema* et *Paraleptophlebia*, les planaires et les oligochètes étaient des taxons retrouvés couramment dans la Miramichi Nord-Ouest en amont du confluent et dans la zone de mélange, mais non dans la Tomogonops.

INTRODUCTION

Ecological problems associated with base metal (principally copper and zinc) contamination of the Little Tomogonops River became apparent in 1960 (Sprague et al. 1965). The possibility of using benthic insects as indicators of water quality was assessed by Sprague et al. (1965), who concluded that mayflies (Ephemeroptera) were the most sensitive order - of roughly the same sensitivity as juvenile salmon (*Salmo salar*). No mayflies were present at that time in the then heavily polluted Tomogonops. Benthic sampling was also performed in 1974-75 (Peterson 1978), the results of which indicated a slight improvement; but the numbers of mayflies collected in the Tomogonops were very low (two in 3 ft^2 samples) as compared to the NW Miramichi (18-202/ft^2). The mixing zone of NW Miramichi and Tomogonops exhibited intermediate densities of mayflies.

In the intervening 20 yr, efforts have continued to reduce the base metal contamination of Tomogonops water, and there was interest in having the 1974-75 sampling repeated for comparative purposes. This report summarizes the results of sampling the benthic invertebrates at the mouth of Little Tomogonops, in the NW Miramichi River upstream of the Tomogonops plume, and in the mixing zone of the two streams.

METHODS

Sampling was performed Aug.22, 1996 in the same stream areas as sampled in 1974-75. Half of the samples was taken with a "Surber" ft^2 sampler with a fine (100 μ) mesh bag, and half with an identical sampler but with a coarser (450 μ) mesh bag. Six samples (three coarse, three fine) were taken in the NW Miramichi upstream of the confluence with the Tomogonops (labelled NW1-6); eight samples (four, four) along the "clean" side of the Miramichi downstream of the confluence where Tomogonops water did not appear to mix with the Miramichi (labelled C1-8); 12 (six, six) in the NW Miramichi - Tomogonops mixing zone (labelled M1-12); six in the "polluted" zone of the NW Miramichi below the confluence (seemingly mostly Tomogonops water, labelled P1-6); and six (three, three) samples were taken from the Little Tomogonops R. (Labelled T1-6). The samples were spaced at about 200-m intervals. For a diagram of the area see Peterson (1978).

All samples were taken from rubble habitat (stones 2.5-6.0 cm diam.) in riffle areas with similar water velocities (not measured) and depths (ca. 15-30 cm). All large rocks within the sampling area were scrubbed, then the bottom was stirred for 1 min to a depth of 30.5 cm with a "claw"-type garden cultivator.

Mayflies (Ephemeroptera) were identified to genus, caddis flies (Trichoptera) and stoneflies (Plecoptera) to either genus or family, true flies (Diptera) to family, Odonata to order, and Coleoptera to family. Other invertebrates were identified to phylum or order. Identification to order, as performed in the past, might be of insufficient sensitivity to detect differences .

RESULTS

Eight mayfly genera were identified (Table 1). All eight were collected in the Northwest samples (NW) above the Tomogonops, five from the "clean" side of the Northwest below the confluence with the Tomogonops, seven from the mixing zone, five from the "polluted" side of the Northwest below the Tomogonops, and three from the Tomogonops. Obviously, mayflies were collected in greater numbers from the Tomogonops and "polluted" side of the Northwest than in 1974 and 1975, when only the fine mesh sampler was used (mean of 43.6 mayflies/sample in 1996 vs. 1-2/sample in 1974-75). However, the number of genera collected in the Tomogonops and "polluted" side of the Northwest were fewer than from the Northwest above the confluence. Epeorus, Stenonema, Tricorythodes and Paraleptophlebia were genera that were not collected or were represented by only one specimen in the "T" and "P" samples.

Fine mesh samples had many more mayflies than samples taken with the coarse mesh sampler. Epeorus, Paraleptophlebia, Pseudocleon and Baetis were mostly represented by early instars that were not retained efficiently by the coarse mesh.

Total numbers of caddis flies collected per sample were similar in all sampling zones (Table 2). Numbers of Trichoptera taxa sampled were less in the "P" and "T" zones (six and five, respectively vs. nine, seven and 10 in the "NW","C" and "M" zones, respectively). However, most of the taxa not collected in the P and T zones were of infrequent occurrence elsewhere (e.g. Psilotreta, Helicopsyche and Chimarra). As with mayflies, the fine mesh sampler

collected more caddis flies, particularly those with mostly earlier instars present (e.g. Hydropsychidae).

Among the various other organisms collected in the sampling (Table 3), the most apparent observation is the absence of planaria and oligochaetes in the samples from the P and T zones.These organisms are in intimate contact with the sediments - the oligochaetes, in particular, would be in subsurface sediments. They also lack the relatively thick chitinous exoskeleton of the insects, and might be more intolerant of base metal contamination in the sediment. The possible lack of oligochaete populations should be further investigated, as their absence may be responsible for the occurrence of loose organic flocculant material present in depositional areas of the Tomogonops and "P" zones.

The fine mesh sampler was obviously more efficient at sampling most organisms, particularly thread-like ones, such as Chirinomidae and oligochaetes that would easily pass through the coarse mesh.

For all three tables (Ephemeroptera, Trichoptera, Miscellaneous), the total number of identified taxa was fewer in the P and T zones: 30 for NW samples, 27 for C samples, 31 for M samples, 21 for P samples and 18 for T samples (Table 4). Taxa which were collected in the NW, C, and M zones, but were absent from the P and T zones, were : Tricorythodes, Isonychia, Psilotreta, planaria and Oligochaeta. Epeorus, Heptagenia, Paraleptophlebia, Lepidostoma and Pteronarcys were not collected from the Tomogonops. Some of these were infrequent in all zones, and their absence might be due to inadequate numbers of samples. This is probably not the case with Epeorus, Stenonema, Paraleptophlebia, planaria and oligochaetes, which were collected in almost every fine mesh sample taken from the NW, C and M zones.

A principal components analysis (see, for example, Zitko 1994) was performed on the 38 samples, with the samples normalized to a total of 100 organisms per sample (to give all samples equal weight in the analysis, Appendix1). A plot of the first PC component against the second PC component (Fig.1) indicates a general trend from low to high diversity in the direction of the arrow. Generally, most of the P and T samples are at the negative ends of both component axes, and most coarse mesh samples are also located in this region. Taking samples with a coarse mesh, and sampling in the T and P zones both tend to reduce the number of taxa present in the samples. Baetidae, Glossomatidae and Hydropsychidae are proportionately of much greater weight in coarse mesh samples, and in samples from the P and T zones. Stenonema and Ceratopogonidae were important in discriminating between C and NW zones and P and T zones, with Odonata, Chironomidae and Heptagenia apparently important on the PC-2 axis as well.

The sample lying at the extreme high end of PC axis 1 was an odd-ball, with overall low diversity, but with high representation of taxa important in characterizing the N and C zones (Heptagenia, oligochaetes) - but no Baetidae or Glossomatidae and low numbers of Chironomidae. The apparently high correlation between sample points on the two PC axes indicates that both axes are influenced largely by the same taxa.

SUMMARY

Mayflies (Ephemeroptera) appear to be present in the Tomogonops River and its zone of greatest influence ("P" zone) in the Northwest Miramichi River in much greater abundance than was the case 20-25 yr ago. To this extent, efforts to improve the water quality have been successful. Nevertheless, the number of taxa collected from the T and P zones was lower than the number collected from the Northwest above the confluence or in the mixing zone. The failure to collect oligochaetes is of interest, and should be further investigated.

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Table 1. Numbers of mayflies of various genera sampled in the Northwest Miramichi and Tomogonops rivers. NW: Northwest Miramichi, upstream of confluence with the Tomogonops; C: "Clean" side of the Northwest Miramichi, along opposite bank from Tomogonops confluence; M: mixing zone of Miramichi and Tomogonops waters; P: "Polluted" side of Northwest Miramichi below confluence with the Tomogonops; T: Tomogonops. Coarse: samples taken with a coarse (450-μ) mesh; fine: samples taken with a fine (100-μ) mesh sample.

Sample site	Sample #	Mesh size	*Epeorus*	*Heptagenia*	*Stenonema*	*Baetis*	*Pseudocleon*	*Tricorythodes*	*Paraleptophlebia*	*Isonychia*	#
NW	1	coarse	1	0	9	0	0	0	0	8	18
	2	coarse	2	1	0	1	1	0	0	0	5
	3	coarse	3	0	0	7	0	2	1	0	13
	4	fine	18	0	12	39	39	0	3	2	113
	5	fine	1	2	10	4	24	3	3	8	55
	6	fine	22	0	5	18	9	0	7	0	61
	Mean	coarse	2	0.3	3	2.7	0.3	0.7	0.3	2.7	11.2
	Mean	fine	13.7	0.7	9	20.3	24	1	4.3	3.3	76.3
C	2	coarse	1	0	2	4	0	0	0	0	7
	3	coarse	0	0	0	1	0	1	0	0	2
	5	coarse	0	0	0	2	0	0	0	0	2
	7	coarse	0	1	0	0	0	0	0	0	1
	1	fine	21	0	2	16	3	0	6	1	49
	4	fine	4	0	4	10	12	2	7	0	39
	6	fine	27	0	4	22	15	1	8	0	77
	8	fine	6	1	14	20	11	1	6	1	60
	Mean	coarse	0.25	0.25	0.5	1.8	0	0.25	0	0	3.0
	Mean	fine	14.5	0.25	6	17	13.7	1	6.8	0.5	56.2
M	1	coarse′	0	0	0	2	1	0	0	0	3
	2	coarse	0	2	3	0	1	1	0	0	7
	5	coarse	0	2	4	0	4	0	2	0	12
	7	coarse	0	0	0	9	0	0	0	0	9
	9	coarse	2	0	0	0	1	0	2	0	5
	11	coarse	3	0	2	5	0	0	0	0	10
	3	fine	6	0	28	25	22	1	11	1	94
	4	fine	3	0	0	13	9	0	0	0	25
	6	fine	3	0	6	10	14	1	4	0	38
	8	fine	23	0	2	74	53	1	7	0	160
	10	fine	3	0	1	77	6	0	0	0	87
	12	fine	4	0	6	10	15	0	2	0	37
	Mean	coarse	0.8	0.7	1.5	2.7	1.2	0.2	0.7	0.2	7.7
	Mean	fine	7	0	7.1	3.48	19.8	0.5	4	0	73.5

Table 1. (cont'd)

Sample site	Sample #	Mesh size	*Epeorus*	*Heptagenia*	*Stenonema*	*Baetis*	*Pseudocleon*	*Tricorythodes*	*Paraleptophlebia*	*Isonychia*	#
P	1	coarse	0	0	0	1	0	0	0	0	1
	2	coarse	0	0	0	2	0	0	0	0	2
	3	coarse	0	0	0	1	0	0	0	0	1
	4	fine	0	0	0	19	21	0	0	0	40
	5	fine	2	1	0	56	16	0	1	0	76
	6	fine	0	0	0	26	15	0	0	0	41
	Mean	coarse	0	0	0	1.3	0	0	0	0	1.3
	Mean	fine	0.7	0.3	0	33.7	17.3	0	0.3	0	52.3
T	1	coarse	0	0	0	3	0	0	0	0	3
	2	coarse	0	0	0	2	3	0	0	0	5
	3	coarse	0	0	0	7	1	0	0	0	8
	4	fine	0	0	0	37	8	0	0	0	45
	5	fine	0	0	1	41	8	0	0	0	50
	6	fine	0	0	0	25	9	0	0	0	34
	Mean	coarse	0	0	0	4	1.3	0	0	0	5.3
	Mean	fine	0	0	1	34.3	8.3	0	0	0	43.0

Table 2. Numbers of caddis flies of various taxa sampled in the NW Miramichi and Tomogonops Rivers. Legend as in Table 1.Taxa are either genus or family.

Sample site	Sample #	Mesh size	*Brachycentrus*	*Glossosomatidae*	*Hydropsychidae*	*Rhyacophilidae*	*Psilotreta*	*Helicopyche*	*Polycentropus*	*Lepidostoma*	Oecetis	Chimarra	#
NW	1	coarse	17	3	45	1	0	0	6	0	0	6	78
	2	coarse	2	18	6	1	0	0	0	0	0	0	27
	3	coarse	2	0	7	0	0	0	0	0	0	0	9
	4	fine	4	22	27	4	2	2	7	5	0	0	73
	5	fine	4	1	12	2	0	0	4	2	0	0	25
	6	fine	0	24	54	1	0	0	3	1	0	1	84
	Mean	coarse	7	7	19.3	0.7	0	0	2	0	0	2	38
	Mean	fine	2.7	15.7	31	2.3	0.7	0.7	4.7	2.7	0	0.3	60.8
C	2	coarse	5	4	13	1	0	0	1	0	0	0	24
	3	coarse	3	0	4	0	0	0	0	0	0	0	7
	5	coarse	0	1	3	0	0	0	0	0	0	0	4
	7	coarse	2	0	2	1	1	0	0	0	0	0	6
	1	fine	16	35	33	1	0	0	0	2	0	0	87
	4	fine	0	0	2	2	1	0	2	0	0	0	7
	6	fine	8	3	29	1	1	0	3	2	0	0	47
	8	fine	3	5	10	0	1	0	10	3	0	0	32
	Mean	coarse	2.5	1.2	85.5	0.5	0.2	0	0.2	0	0	0	10.2
	Mean	fine	6.8	10.8	18.5	1	0.8	0	3.8	1.8	0	0	43.2
M	1	coarse	12	0	6	1	0	0	1	0	0	0	20
	2	coarse	2	2	1	0	0	0	0	0	1	0	6
	5	coarse	2	0	0	0	0	0	1	4	1	0	8
	7	coarse	5	1	15	0	0	0	0	0	0	0	21
	9	coarse	3	5	7	0	0	1	1	0	0	0	16
	11	coarse	5	10	9	1	0	0	0	0	0	0	25
	3	fine	6	3	41	1	0	0	6	7	1	1	66
	4	fine	17	9	63	1	0	0	1	1	0	0	92
	6	fine	4	7	25	0	0	0	1	2	1	0	41
	8	fine	36	0	95	2	0	0	2	2	2	3	142
	10	fine	22	0	72	2	0	0	8	1	0	0	105
	12	fine	2	1	11	0	0	0	2	0	0	0	16
	Mean	coarse	4.8	3	6.3	0.3	0	0.2	0.5	0.7	0.3	0	16.0
	Mean	fine	14.5	3.3	51.2	1	0.2	0	3.3	2.2	0.7	0.7	76.8

Table 2. (cont'd)

Sample site	Sample #	Mesh size	*Brachycentrus*	*Glossosomatidae*	*Hydropsychidae*	*Rhyacophilidae*	*Psilotreta*	*Helicopyche*	*Polycentropus*	*Lepidostoma*	Oecetis	Chimarra	#
P	1	coarse	1	5	8	2	0	0	0	0	0	0	16
	2	coarse	0	0	2	0	0	0	0	0	0	0	2
	3	coarse	5	4	5	1	0	0	0	0	0	0	15
	4	fine	4	7	16	2	0	0	3	0	0	0	32
	5	fine	21	33	60	1	0	0	4	1	0	0	120
	6	fine	35	3	48	3	0	0	0	0	0	0	89
	Mean	coarse	2	3	5.7	1	0	0	0	0	0	0	11.0
	Mean	fine	20	4.3	41.3	2	0	0	2.3	0.3	0	0	80.3
T	1	coarse	2	6	11	0	0	0	0	0	0	0	19
	2	coarse	10	4	3	1	0	0	0	0	0	0	18
	3	coarse	4	16	4	2	0	0	0	0	0	0	26
	4	fine	5	7	80	8	0	0	0	0	0	0	100
	5	fine	4	7	40	3	0	0	1	0	0	0	55
	6	fine	11	5	31	1	0	0	1	0	0	0	49
	Mean	coarse	5.3	8.7	6	1	0	0	0	0	0	0	21
	Mean	fine	6.7	6.3	50.3	4	0	0	0.3	0	0	0	68.0

Table 3. Numbers of miscellaneous organisms of various taxa sampled from the NW Miramichi and Tomogonops Rivers. The first 3 taxa are stoneflies (Plecoptera), the next 5 are Diptera. Taxa are genus, family, or order.

Sample site	Sample #	Mesh size	Plecoptera														
			Perlidae	*Pteronarcys*	unk.	*Chironomidae*	*Simuliidae*	*Tipulidae*	*Ceratopogonidae*	*Atherix*	Odonata	*Elmidae*	*Sialidae*	Planaria	Oligochaeta	#
NW	1	coarse	1	0	0	26	4	1	1	0	2	2	1	2	7	47
	2	coarse	0	0	0	2	0	1	1	0	3	0	0	0	0	7
	3	coarse	2	0	1	7	0	0	0	0	1	0	0	1	0	12
	4	fine	1	0	31	180	4	10	8	0	27	0	0	3	39	303
	5	fine	2	3	6	183	0	1	5	1	12	1	0	3	4	221
	6	fine	8	0	50	384	45	4	14	1	3	0	0	3	57	569
	Mean	coarse	1	0	0.3	11.7	1.3	0.7	0.7	0	2	0.7	0.3	1	2.3	21.3
	Mean	fine	3.7	1	29	249	16.3	5	9	0.7	14	0.3	0	3	33.3	364.3
C	2	coarse	1	0	2	13	0	0	3	1	1	0	1	0	6	28
	3	coarse	0	0	0	5	0	0	1	1	0	0	0	0	0	7
	5	coarse	1	0	0	9	0	0	1	1	1	0	0	0	0	13
	7	coarse	0	0	1	5	0	0	0	0	1	2	1	1	2	13
	1	fine	5	0	10	99	1	2	8	4	2	1	0	0	20	152
	4	fine	0	0	15	257	0	3	16	0	4	1	1	2	39	338
	6	fine	1	0	17	142	0	1	6	2	3	0	0	2	16	190
	8	fine	3	0	13	226	0	4	16	0	9	1	0	2	47	321
	Mean	coarse	0.5	0	0.8	8	0	0	1.2	0.8	0.8	0.5	0.5	0.2	2	15.2
	Mean	fine	2.2	0	13.8	181	0.2	2.5	11.5	1.5	4.5	0.8	0.2	1.5	30.5	250.2
M	1	coarse	0	0	0	6	0	0	3	0	0	0	0	0	0	9
	2	coarse	0	0	0	17	0	0	1	0	1	0	0	0	0	19
	5	coarse	0	0	1	37	0	0	7	1	5	0	0	0	0	51
	7	coarse	0	0	0	23	0	0	0	0	2	0	0	0	0	25
	9	coarse	1	0	1	10	2	0	1	0	3	0	0	0	1	19
	11	coarse	0	1	0	4	1	1	0	0	1	0	0	0	0	8
	3	fine	1	4	31	439	0	5	5	0	22	1	0	0	3	511
	4	fine	0	2	37	216	1	5	15	2	2	2	0	0	0	282
	6	fine	0	2	11	173	0	0	7	2	5	0	0	5	3	208
	8	fine	2	2	53	316	11	11	14	1	14	5	0	0	3	432
	10	fine	0	0	41	381	0	4	13	2	6	4	1	0	9	461
	12	fine	0	1	13	191	0	3	2	0	5	0	0	1	2	218
	Mean	coarse	0.2	0.2	0.3	16.2	0.5	0.2	2	0.2	2	0	0	0	0.2	21.8
	Mean	fine	0.5	1.8	31	286	2	4.7	9.3	1.2	9	0 2	0.2	1	3.4	352.0

Table 3. (cont'd)

Sample site	Sample #	Mesh size	*Perlidae*	*Pteronarcys*	Plecoptera unk.	*Chironomidae*	*Simuliidae*	*Tipulidae*	*Ceratopogonidae*	*Atherix*	Odonata	*Elmidae*	*Sialidae*	Planaria	Oligochaeta	#
P	1	coarse	0	0	0	29	0	0	1	0	1	0	0	0	0	31
	2	coarse	0	0	0	4	0	0	0	0	2	0	0	0	0	6
	3	coarse	1	0	0	13	0	0	0	0	1	0	0	0	0	15
	4	fine	0	1	30	122	0	1	3	0	1	2	0	0	0	160
	5	fine	0	0	19	146	0	3	6	2	7	2	1	0	0	186
	6	fine	0	0	22	198	0	2	6	3	2	3	0	0	0	236
	Mean	coarse	0.33	0	0	15.3	0	0	0.3	0	1.3	0	0	0	0	17.3
	Mean	fine	0	0.3	23.7	155.3	0	2	5	1.7	3.3	2.3	0.3	0	0	194.0
T	1	coarse	1	0	0	2	2	0	0	0	0	1	0	0	0	6
	2	coarse	0	0	1	5	0	0	1	0	1	0	0	0	0	8
	3	coarse	0	0	0	3	0	0	0	2	0	0	0	0	0	5
	4	fine	1	0	51	109	3	2	14	0	4	4	1	0	0	389
	5	fine	0	0	35	100	0	1	2	0	9	1	0	0	0	148
	6	fine	0	0	13	57	0	0	0	1	1	0	0	0	0	72
	Mean	coarse	0.3	0	0.3	3.3	0.7	0	0.3	0.7	0.3	0.3	0	0	0	6.3
	Mean	fine	0.3	0	33	155.3	1	1	5.3	0.3	4.7	1.7	0.3	0	0	203.0

Table 4. Summary of total taxa and organisms collected in the various zones.

NW: Northwest R. above confluence C: Northwest R. below confluence, but not apparent mixing M: Mixing zone of Northwest & Tomogonops P: Mainly Tomogonops water T: Tomogonops R. above confluence
NW Mean # taxa/sample: Fine: 25 Coarse: 16 Mean # organisms/sample: Fine: 515.7 Coarse: 74.7
C Mean # taxa/sample: Fine: 22.5 Coarse: 12.2 Mean # organisms/sample: Fine: 372.0 Coarse: 29.5
M Mean # taxa/sample: Fine: 23 Coarse: 12.2 Mean # organisms/sample: Fine: 487.5 Coarse: 47.2
P Mean # taxa/sample: Fine: 18.7 Coarse: 6.7 Mean # organisms/sample: Fine: 306.3 Coarse: 30.7
T Mean # taxa/sample: Fine: 16.7 Coarse: 9.0 Mean # organisms/sample: Fine: 296.0 Coarse: 35.0

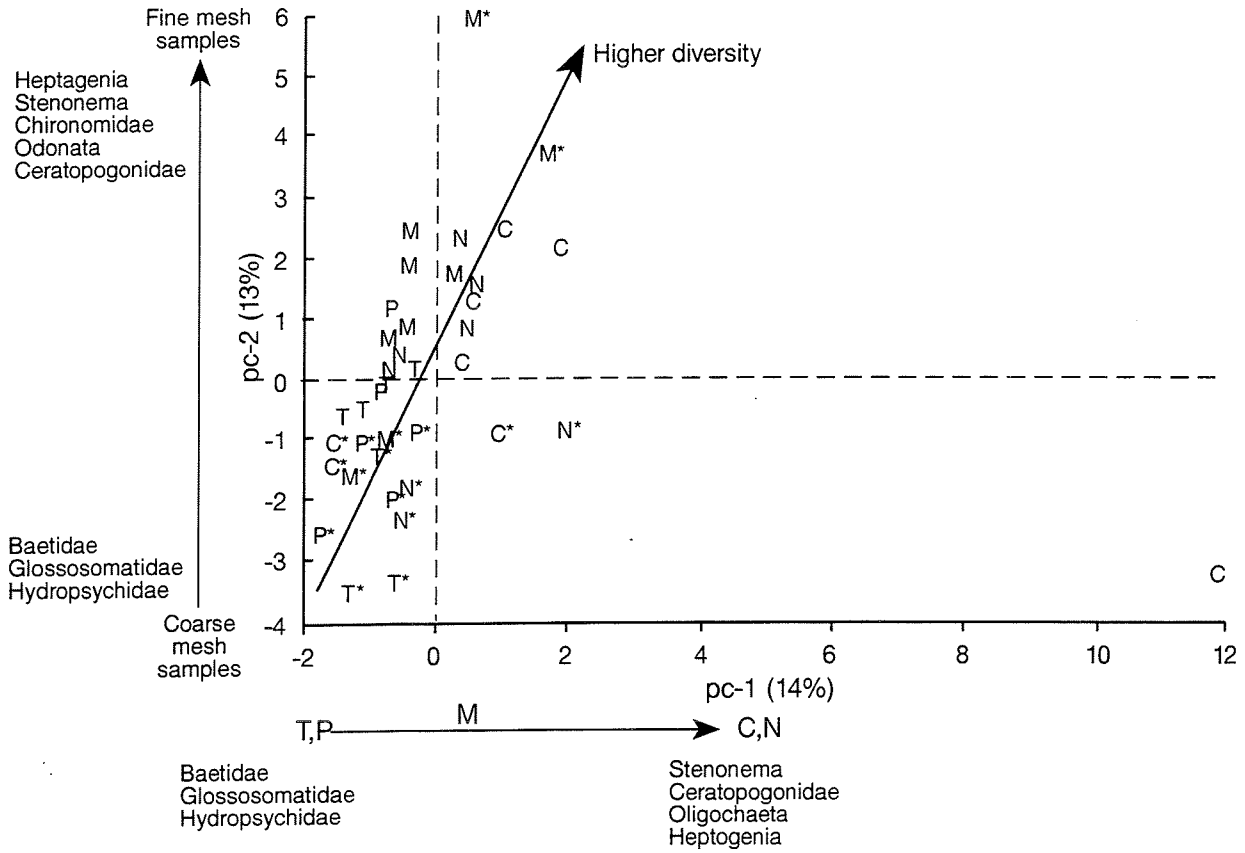

Fig.1. Benthic samples are arrayed on a grid of the first 2 principal components of a PC analysis based on the relative numbers of the various taxa listed in Tables 1 to 3.N: Northwest Miramichi samples; C: "Clean" samples (as described in Table 1); M, P, and T as described in Table 1. Samples accompanied by an asterisk are coarse samples. The arrow on the grid is a trend line drawn by eye, and indicates a tendency toward increasing numbers of taxa.Arrows outside the axes represent our impression of the factors important in determining the location of samples along the two component axes.The taxa listed at each end of these arrows represent taxa that were influential in determination of sample position on the PC grid. Percentages in parentheses show percent of total variance accounted by each component.