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A Macroinvertebrate Community Index of Water Quality for Stony Streams

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A Macroinvertebrate Community Index of Water Quality for Stony Streams

by

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A Macroinvertebrate Community Index (MCI), based upon principles of the British National Water Council's Biological Monitoring Working Party score system, is proposed and evaluated for assessment of organic pollution in stony streams in Taranaki, North Island, New Zealand. Application of the MCI to data collected from streams and rivers elsewhere in the North and South Islands of New Zealand has produced interpretations consistent with those based upon quantitative and descriptive analyses, suggesting that the MCI may prove useful throughout the country. The MCI utilises presence/absence freshwater invertebrate distributional data and may have advantages over traditional biological quantitative analyses for use in water management.

The application and potential uses of the MCI are discussed and work required for further development of the index is suggested.

Keywords: Taranaki, index, streams, macroinvertebrates, organic pollution.

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CONTENTS

1 Introduction

Many kinds of organisms (e.g. bacteria, algae, macrophytes, macroinvertebrates, fish) have been examined for their ability to reflect water quality conditions (Tesmer and Wefring, 1981) but, because much research still is required, no organism or group of organisms has proven to be a universal indicator of all types of pollution. Stream macroinvertebrate communities have received more attention than other freshwater ecosystem components as a means of assessing the impacts of water quality changes (Hellawell, 1977).

The assumption underlying the use of macroinvertebrate community analyses as a means of water quality assessment in streams and rivers is that the community present in a given situation is a product of its environment. Furthermore, significant variation in community composition between, for example, polluted and unpolluted waters, may be a result of different tolerances or habitat preferences that individual taxa exhibit.

Biological methods of water quality assessment have the advantage of being able to summarise river conditions over a relatively long term as opposed to spot chemical analyses which indicate conditions at a single point in time (Winterbourn, 1981). This fact, combined with the lack of long-term chemical water quality records, however, makes it extremely difficult to derive numerical relationships between invertebrate community parameters and chemical features of the water.

Although numerous methods have been developed for the collection, processing and interpretation of data on macroinvertebrate communities for biological monitoring (see reviews by Hellawell, 1977; Burns, 1979; Winterbourn, 1981) most require quantitative data and, as such, are relatively tedious and costly. In addition, biologists in a regional water board must explain their findings to non-biologists, e.g., managers, engineers, soil conservators, or to the general public (Mason, 1981).

The increasing emphasis placed on biological monitoring in the northern hemisphere (especially Europe) has resulted in the development of score systems and biotic indices that reduce complex biological information to single numbers (see reviews by Hellawell 1977, 1978; Mason 1981). These techniques, based upon presence/absence or semi-quantitative data might be much less time consuming than quantitative studies. Although there is necessarily a reduction in ecological information content, the results often are more understandable to non-biologists and can be generated relatively quickly for making decisions involving the management of water resources (Armitage, *et al.*, 1983).

The British National Water Council's Biological Monitoring Working Party (1978) produced a macroinvertebrate-based score system to assess the biological condition of rivers throughout the United Kingdom. This paper describes a procedure adopted to apply the principles of the Biological Monitoring Working Party score system to freshwater invertebrate distributional data in New Zealand and is based on a study of riffles in stony streams which formed part of the Taranaki Ringplain Water Resources Survey which together with a preliminary form of the Macroinvertebrate Community Index (MCI), was described by Taranaki Catchment Commission (1984a). It should be noted here that, originally, these data were not collected with a view to developing a biological index. Most notably, there is a lack of associated water quality data which could have been used to classify sites initially and then be correlated with the classification based upon the biological index. Furthermore, this attempt to utilise inadequate existing data (especially with respect to describing relationships between biological index values and physical or chemical variables) means that some of this discussion can only hint at the potential of the index.

The approach adopted in this study involved:

1. division of stream sites into three pollutional classes;
2. derivation of MCI scores for each taxon occurring in each of the pollutional classes;
3. analysis of the MCI scores to determine if they correspond to the three pollutional classes originally identified.

Clearly a problem of circularity arises here, and the approach used does not provide a true test of the applicability of the technique—to do this, application of the MCI to an independent data set would be necessary. An attempt to minimise circularity was made by using combined seasonal data to guide score allocation to each taxon followed by application of the MCI to separate seasonal data. It was considered that the approach adopted would at least provide an indication of the potential applicability of MCI to macroinvertebrate stream communities in New Zealand, although clearly its performance can only be properly evaluated by application to a data set(s) from outside Taranaki.

Examples of the application of the index to macroinvertebrate community composition data from within Taranaki and elsewhere in New Zealand are presented and work required for further development and corroboration of the technique is outlined.

2 Study Area

Approximately 90 rivers and streams enter the sea around the coast of Taranaki on the west coast of New Zealand's North Island. The majority arise on Mount Egmont (summit 2518 m above msl) and flow through native podocarp-hardwood forest to the boundary of Egmont National Park (460–550 m above msl). Most streams and rivers are relatively short (20–50 km) and steep and flow across the ringplain surrounding the mountain through intensive dairy, beef, sheep or pig farmland. Many rivers have remnants of riparian native bush along their upper reaches but pasture grasses, willows or conifers tend to be more prevalent downstream. Stony or bouldery substrata and pool-/run/riffle configurations are typical. A number of these waterways receive point source organic discharges of abattoir, tannery, dairy factory, piggery or oxidation pond (farm and municipal) effluent and, in addition, most are subject to diffuse-source nutrient enrichment of runoff from farmland. Steep gradients and turbulent conditions ensure that stream water normally is saturated with oxygen and that effluent inputs are well mixed.

3 Methods

3.1 Field Work and Sample Processing

Single samples of benthic invertebrates were obtained from 35 stony riffle sites on 13 waterways on the Taranaki ringplain (Appendix 1) during low flows of winter 1981 (22 July–7 August), spring 1981 (15 October–29 October) and summer 1982 (29 January–10 February) (Taranaki Catchment Commission, 1984a). Invertebrates were collected using a 0.5 mm mesh hand net (0.35 m diameter circular frame) and the 'kick-sample' technique. To standardise sampling further, collections were made by kicking the substratum vigorously within 0.5 m of the net opening and the duration of sampling was limited to 10 seconds since most swiftly-flowing ringplain streams had very high densities of invertebrates. Samples were transferred to pottles and preserved in 70 percent alcohol. Subsequently, animals were separated from debris by wet sieving (2 mm, 1 mm and 0.5 mm mesh sieves), identified and counted (for winter and summer samples only) using an Olympus VMZ stereomicroscope at 10X—40X magnification. Identifications were made with reference to taxonomic works by:

Cowley (1978)—Trichoptera
Chapman and Lewis (1976)—Crustacea and Acarina
Mason (1974)—Hirudinea
McFarlane (1951)—Trichoptera
Pennak (1978)—General
Winterbourn and Gregson (1981)—Insecta
Winterbourn (1973)—Mollusca

Four interrelated environmental factors affect the microdistribution of stream benthos (Cummins and Lauff, 1969). These are, substratum particle size, food, current velocity and other physico-chemical factors (i.e., water quality). In the present study, substratum and current effects were minimised by sampling only in fast-flowing stony riffles where the faunas present are most likely to respond clearly to changing conditions (Hynes, 1960). No attempt was made to develop numerical relationships between MCI values and physico-chemical measures of water quality variables because the latter were available only as spot measurements and were considered to be of limited value. Instead, development and evaluation of the index were based on the premise that there should be a progressive decrease in MCI moving down a river that flows through farmland and which is subject to organic enrichment via runoff etc., and that MCI values should be lower still at sites below organic effluent discharges than at sites above them.

4 Development of the Macroinvertebrate Community Index (MCI)

4.1 The principle of the Biological Monitoring Working Party (BMWP) index

BMWP (1978) proposed a system for Great Britain in which scores (from 1 to 10) were allocated to families of freshwater invertebrates with pollution intolerant families gaining higher scores than pollution tolerant families (Table 1). Scores were assigned to families on the basis of questionnaires, surveys and discussion (Armitage *et al.* 1983). The index was applied by summing the scores for each family present at a site to obtain a site score. Armitage *et al.* (1983) recognised that site scores could be rather misleading for comparative purposes since these are influenced unduly by presence/absence of particular taxa, which may be more an artefact of sampling effort than an indication of differences in community composition—a conclusion that I had reached independently, during initial development of the MCI in early 1983. Therefore, Armitage *et al.* (1983) proposed that the site score be divided by the number of (scoring) taxa in the sample to give an average score per taxon (ASPT). The ASPT is less subject to variation related to sampling effort or seasonal change.

Table 1: Scores allocated to invertebrate families for the British Biological Monitoring Working Party (1978) score system

Families	Score
Siphlonuridae Heptageniidae Leptophlebiidae Ephemerellidae Potamanthidae Ephemeridae Taeniopterygidae Leuctridae Capniidae Perlodidae Perlidae Chloroperlidae Aphelocheiridae Phryganeidae Molannidae Beraeidae Odontoceridae Leptoceridae Goeridae Lepidostomatidae Brachycentridae Sericostomatidae	10
Astacidae Lestidae Agriidae Gomphidae Cordulegasteridae Aeshnidae Corduliidae Libelluidae Psychomyiidae Philopotamidae	8
Caenidae Nemouridae Rhyacophilidae Polycentropodidae Limnephilidae	7
Neritidae Viviparidae Ancylidae Hydroptilidae Unionidae Corophiidae Gammaridae Platycnemididae Coenagriidae	6
Mesoveliidae Hydrometridae Gerridae Nepidae Naucoridae Notonectidae Pleidae Corixidae Haliplidae Hygrobiidae Dytiscidae Gyrinidae Hydrophilidae Clambidae Helodidae Dryopidae Elminthidae Chrysomelidae Curculionidae Hydropsychidae Tipulidae Simuliidae Planariidae Dendrocoelidae	5
Baetidae Sialidae Piscicolidae	4
Valvatidae Hydrobiidae Lymnaeidae Physidae Planorbidae Sphaeriidae Glossiphoniidae Hirudidae Erpobdellidae Asellidae	3
Chironomidae	2
Oligochaeta (whole class)	1

4.2 Application of the BMWP index to New Zealand

Application of the ASPT (using family level taxa) to Taranaki ringplain invertebrate data, including 18 families (of the 37 collected) which had been scored by BMWP, revealed that the ASPT did not discriminate between unenriched and slightly to moderately enriched sites although grossly enriched conditions were distinguished. Consequently, in many cases, ASPT did not produce easily explainable patterns of change downstream when applied to individual rivers.

It was readily apparent that the familial-based BMWP system was relatively insensitive, not only as indicated above, but also because different genera within families can vary widely in their responses to water quality. For example, BMWP (1978) scored the caddisfly family Sericostomatidae (= Conoesucidae) 10, but in New Zealand the conoesucid *Pycnocentrodes* was considered by Hirsch (1958) to be tolerant of a considerable degree of pollution, whereas *Beraeoptera* was recorded only in the upper reaches of streams above the entrance of serious pollution.

Hynes (1960) and Hawkes (1962) maintained that gross pollution affects whole taxonomic groups of macroinvertebrates rather than individual species and Mason (1981) stated that specific differences only become important in cases of mild pollution. This suggests that an index capable of discriminating between clean conditions and, slight, moderate and gross pollution will need to be based primarily on invertebrate species or genera.

Consequently, it was decided to develop a system in which scores were allocated primarily to genera. Higher taxa (orders, families or tribes) were used only if taxonomic or practical difficulties prevented generic discrimination.

4.3 Allocation of scores to New Zealand taxa

Invertebrate relative abundance data (Appendix II) for combined winter and summer samples of invertebrates from Taranaki ringplain streams were used to guide allocation of scores to taxa using the procedure outlined below. This technique also may be used to extend the list of taxa included in the MCI or to derive a set of scores from another data set independently.

Sites considered characteristic of three pollutional classes were selected using prior knowledge of water quality, effluent discharge type and quality, and land use (Appendix I, Table 2). Eight sites could not be assigned unambiguously *a priori* to pollutional classes

Table 2: Sites allocated to three pollutional classes for use in guiding allocation of scores to taxa (mostly genera) using combined winter and summer quantitative data

	Pollutional Class I	Pollutional Class II	Pollutional Class III
Characteristics	unpolluted	slight to moderate pollution	moderate to gross pollution
Pollution sources	none known	farmland runoff or mild point-source discharges	gross point-source organic discharges
Sites	Manganui A Maketawa A Waiongana A Mangaoraka A Waiwakaiho A Timaru A Stony A Kapoaiaia A Punehu A Kaupokonui A Inaha A Waingongoro A	Kahouri A Kahouri B Kahouri C Mangaoraka B Waiwakaiho B Punehu B Inaha B Waingongoro C Waingongoro D	Kahouri D Waiongana D Kapoaiaia Bi Kapoaiaia Bii Kaupokonui C Inaha C
	12 sites	9 sites	6 sites

and therefore were not used in the score allocation procedure. A guide for score allocation was obtained by calculating, for each taxon (usually genus), the mean percentage contribution to total invertebrate numbers per site for each of the three pollutional classes (I–III) and by applying the following relationship for each taxon (genus), e.g., *Nesameletus*:

	Pollutional Class						
	I		II		III		
Mean % representation	5.58%		1.64%		0%		
Sum of Percentages	5.58	+	1.64	+	0	=	7.22%

$$\text{Approx. Score} = \frac{5.58}{7.22} \times 10 + \frac{1.64}{7.22} \times 5 + \frac{0}{7.22} \times 1$$

$$= 8.86 \quad \ldots \text{roundoff} \ldots \; 9.$$

Since '10' represents a top score, '5' an average score and '1' a low score, this procedure weights the generic score towards the pollutional class/es in which the genus has best representation.

A guide for score allocation could have been obtained from presence/absence data by determining the number of sites at which each genus was represented in each pollutional class (rather than the mean percentage representation) and expressing this as a proportion of the sum of the sites,

i.e., for each genus

$$\text{Approx. score} = \frac{SI}{ST} \times 10 + \frac{SII}{ST} \times 5 + \frac{SIII}{ST} \times 1$$

where SI, SII and SIII are the number of sites in each pollutional class at which the genus was recorded, and ST = SI + SII + SIII.

However, to be reliable, it is likely that data from a large number of sites (say > 100) would be required, and this technique is unlikely to have the sensitivity of the percentage based system. For example, if two taxa were present at the same sites—some in each pollutional class—they would be allocated the same score, However, suppose that 90 percent of the individuals of the first taxon were collected from sites in pollutional class I (clean sites) and 90 percent of individuals of the second taxon were collected from sites in pollutional class III (grossly polluted), then it is reasonable to argue that taxon I is more characteristic of clean sites and taxon 2 more characteristic of grossly polluted sites—even though they are found elsewhere. I believe that the scores allocated to taxa should reflect such differences in relative distribution among pollutional classes and this is achieved by the percentage-based guide for score allocation.

This numerical procedure for guiding score allocations is a reliable guide only if:

1 the three pollutional classes of sites truly represent
I unpolluted streams
II slightly to moderately polluted streams, and
III grossly polluted streams;
2 substrate type is fairly consistent between groups, e.g., all sites are stony riffles; and
3 taxa are recorded in reasonable numbers. Scores derived for taxa represented by one or two individuals at only one site group may be most misleading. In these cases, scores were derived entirely by professional judgement.

Scores allocated to the 68 taxa recorded from Taranaki ringplain streams are listed in Table 3. About 70 percent of the scores were obtained directly by applying the numerical procedure for guiding score allocation described previously. Of the abundant taxa, scores were modified by ± 1 point for *Coloburiscus* (+1), *Deleatidium*, Orthocladiinae and *Chironomus* (all −1). Modifications were based on professional experience, knowledge of habitat requirements obtained from the literature (see Winterbourn 1981 and references therein), or reference to other sets of invertebrate distributional data. Scores for 19 taxa present infrequently in samples also were determined in this way. Scores derived by Hilsenhoff (1977) for his Biotic Index, and BMWP (1978) for the score system (or ASPT) were allocated entirely by professional judgement.

Table 3: Scores allocated to invertebrate taxa collected from stony riffles, during the Taranaki ringplain biological survey, for use in calculation of Macroinvertebrate Community Index (MCI) values.
*Scores obtained by professional judgement or which differed by ± 1 from scores derived using the equation in Appendix II.

Ephemeroptera	
Ameletopsis	10
Nesameletus	9
Coloburiscus	9*
Zephlebia	7
Deleatidium	8*
Atalophlebioides	9*
Mauiulus	5
Austroclima	9
Plecoptera	
Stenoperla	10
Megaleptoperla	9
Zelandoperla	10
Zelandobius	5
Acroperla	5*
Hemiptera	
Microvelia	5*
Megaloptera	
Archichauliodes	7
Coleoptera	
Elmidae	6
Ptilodactylidae	8
Staphylinidae	5
Hydrophilidae	5*
Hydraenidae	8
Dytiscidae	5*
Diptera	
Limonia	6*
Aphrophila	5
Eriopterini	9
Psychodidae	1
Mischoderus	4*
Tanypodinae	5*
Podonominae	8*
Maoridiamesa	3
Orthocladiinae	2*
Polypedilum	3
Chironomus	1*
Tanytarsini	3
Diptera (Cont.)	
Ceratopogonidae	3
Austrosimulium	3
Stratiomyidae	5
Empididae	3
Muscidae/Anthomyiidae	3
Tabanidae	3*
Trichoptera	
Orthopsyche	9
Aoteapsyche	4
Polyplectropus	8
Hydrobiosis	5
Psilochorema	8
Neurochorema	6
Hydrochorema	9*
Costachorema	7
Tiphobiosis	6
Oxyethira	2
Paroxyethira	2*
Pycnocentria	7
Beraeoptera	8
Pycnocentrodes	5
Confluens	5
Conuxia	8*
Olinga	9
Oeconesidae	9*
Helicopsyche	10
Triplectides	5
Crustacea	
Amphipoda	5
Oligochaeta	1
Hirudinea	3*
Platyhelminthes	3*
Mollusca	3
Potamopyrgus	4
Physa	3
Latia	3*
Acarina	5
Nematoda	3*

4.4 Calculation of the MCI

The BASIC computer program for creating data files and calculating MCI values is listed in Appendix III. MCI values were calculated by summing individual taxa scores (from Table 3) for all genera (or higher taxa) present in a sample to obtain a site score. The site score was divided by the number of scoring taxa and multiplied by 20 (a scaling factor) to obtain the MCI value which can range from 0 (when no taxa are present) to 200 (when all taxa present score 10 points each),

$$\text{i.e., MCI} = \frac{\text{site score}}{\text{no. of scoring taxa}} \times 20$$

In practice the minimum MCI for a sample/site is 20 (When all taxa present score 1 point each) and MCI values are rounded to the nearest integer.

The MCI is, in effect, a scaled version of the ASPT applied primarily at the generic rather than familial level.

4.5 Version of the MCI for quantitative data

Although a major objective of the MCI was to reduce the time and expense concerned with biological pollution assessment by utilising invertebrate presence/absence data, there may arise situations where a version of the index using quantitative biological data is desirable. For example, in very swift rivers which have a number of different pollution sources entering within a few kilometres of each other, sampling sites will, of necessity, be close together. In such cases, invertebrate drift can be very marked such that very similar faunal lists may be obtained from all sites, even though there may be marked changes in invertebrate community numerical or percentage composition. A presence/absence analysis would be inadequate in such a situation and a quantitative version of the MCI, (utilising the same generic scores (Table 3) would be more applicable for summarising complex biological data for assimilation by non-biologists.

i.e., $QMCI = \sum_{i=1}^{s} \frac{(n_i * a_i)}{N}$

where n_i =number of individuals in the i^{th} scoring taxon
a_i =score for that taxon (assigned value from 1 to 10 with 1 representing grossly polluted and 10 representing very clean conditions), and
N =total number of individuals collected.

The QMCI is very similar to the index of Chutter (1972), in Winterbourn (1981) (who used scores from 0 to 10) and the Biotic Index of Hilsenhoff (1977) (Scores 0 to 5, but 0 was clean and 5 was polluted).

The QMCI is not discussed further in this publication but certainly warrants further evaluation.

5 Results

5.1 Introduction

Invertebrate counts (winter and summer samples) and presence/absence data (spring samples) for 35 stony riffle sites on 13 Taranaki ringplain streams are presented in Appendix II. Sixty-eight taxa (mostly genera) were recorded. Identifications given in Appendix II are at the level appropriate for the application of the MCI—for more specific identifications see Taranaki Catchment Commission (1984a). Results of MCI analyses for winter, spring and summer sampling are depicted on the MCI vs number of scoring taxa graphs (Figures 1–3) and on the map of Taranaki for combined seasons MCI values (Figure 4). Three site groups based upon subjective assessments of water quality also are shown. Cut-off points between groups I (unpolluted) and II (slight to moderate pollution) and between groups II and III (moderate to gross pollution) are represented by MCI values of 120 $\pm$ 5 and 100 $\pm$ 5 respectively.

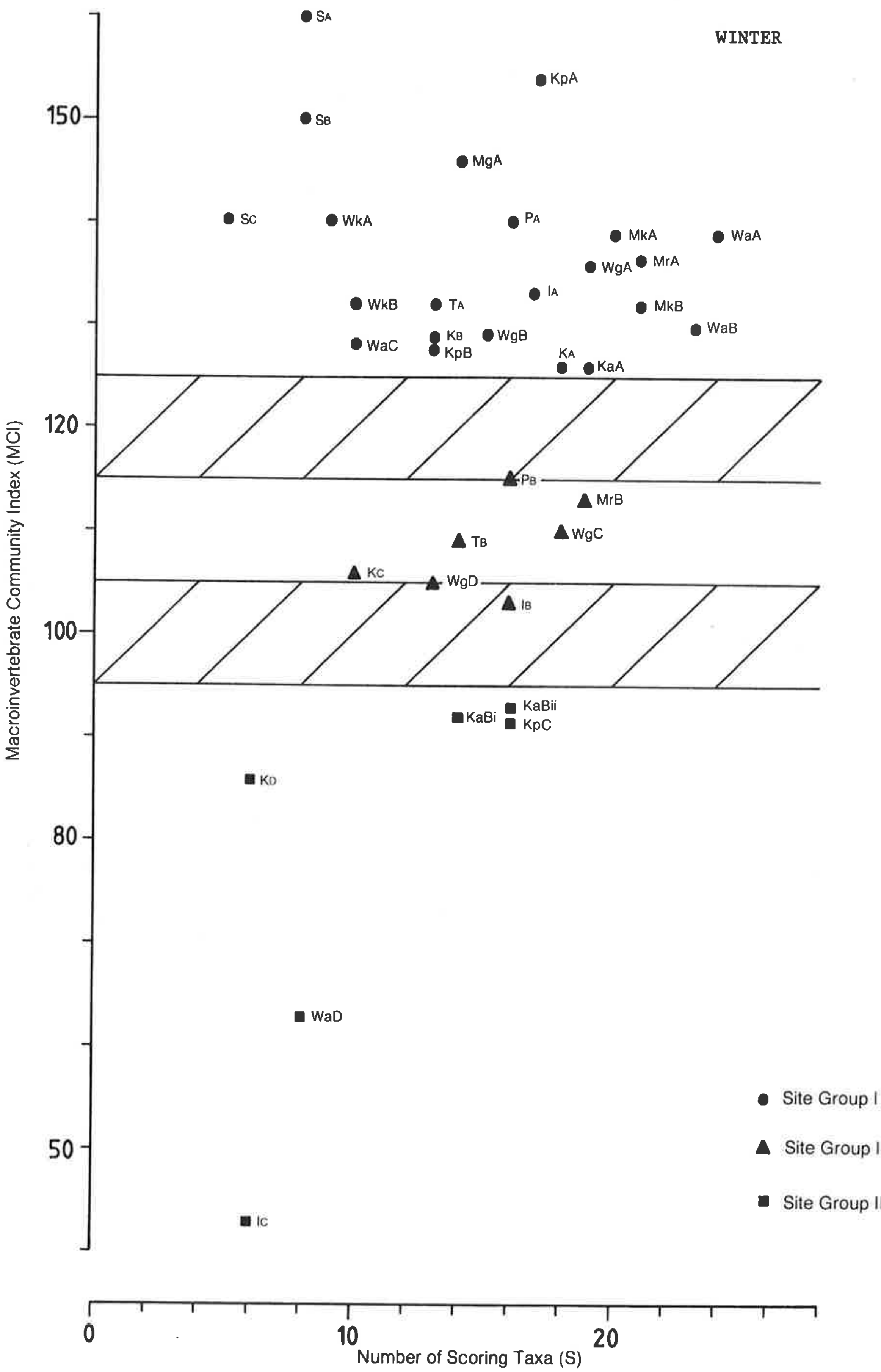

Figure 1: Relationship between MCI and number of scoring taxa for winter invertebrate samples from 35 stony riffle sites on 13 streams on the Taranaki ringplain. Horizontal bands show separation of site groups.

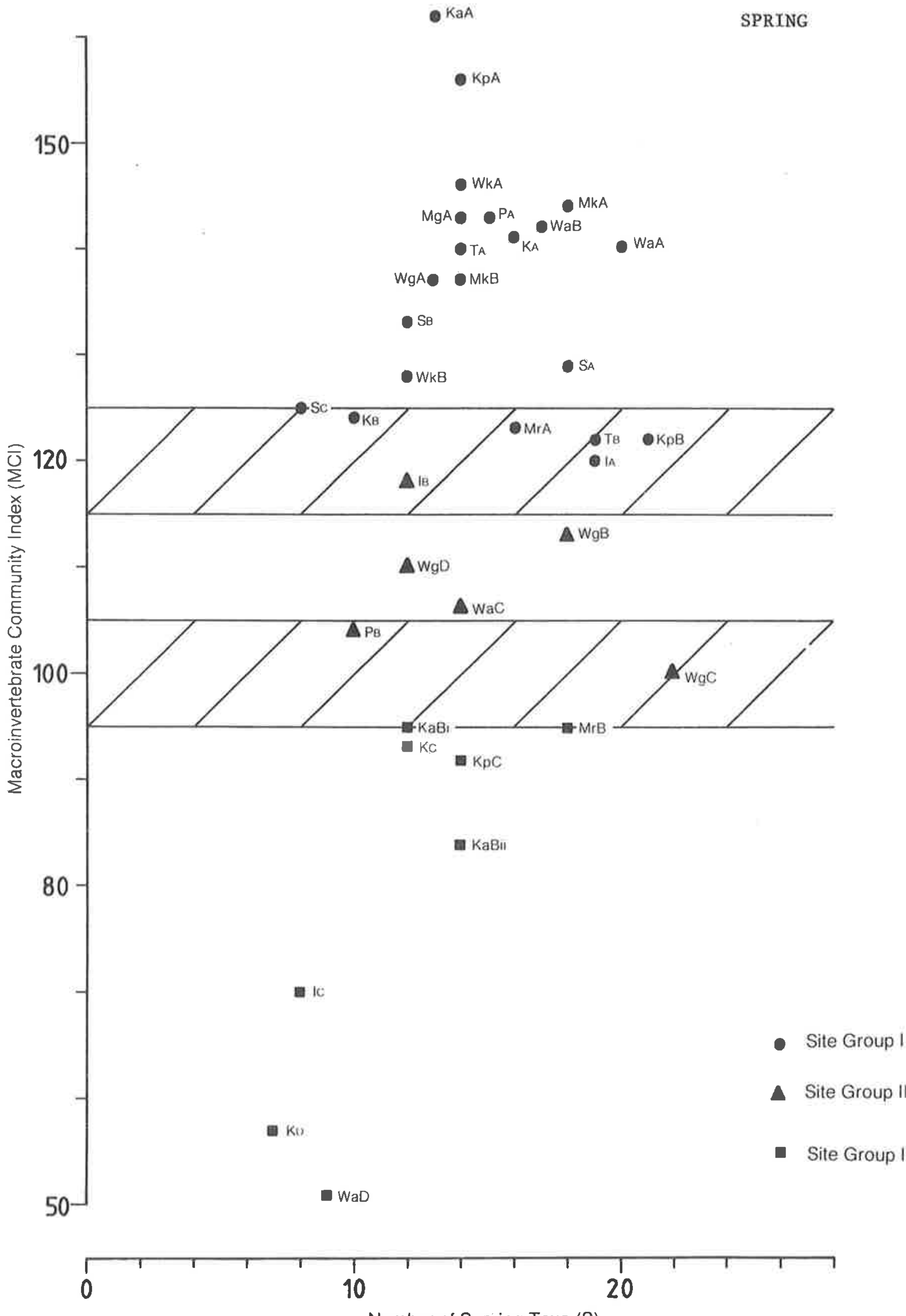

Figure 2: Relationship between MCI and number of scoring taxa for spring invertebrate samples from 35 stony riffle sites on 13 streams on the Taranaki ringplain. Horizontal bands show separation of site groups.

SUMMER

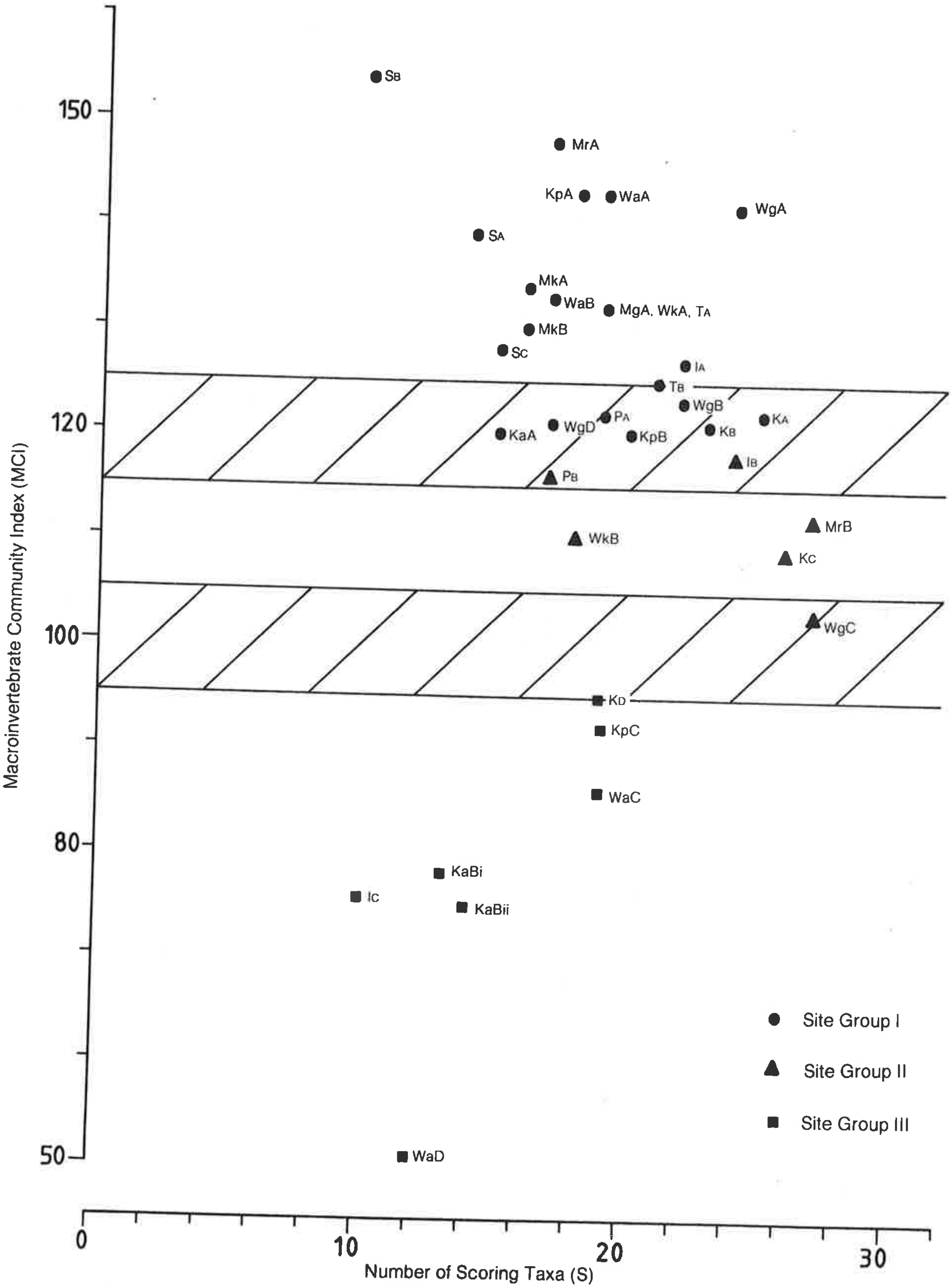

Figure 3: Relationship between MCI and number of scoring taxa for summer invertebrate samples from 35 stony riffle sites on 13 streams on the Taranaki ringplain. Horizontal bands show separation of site groups.

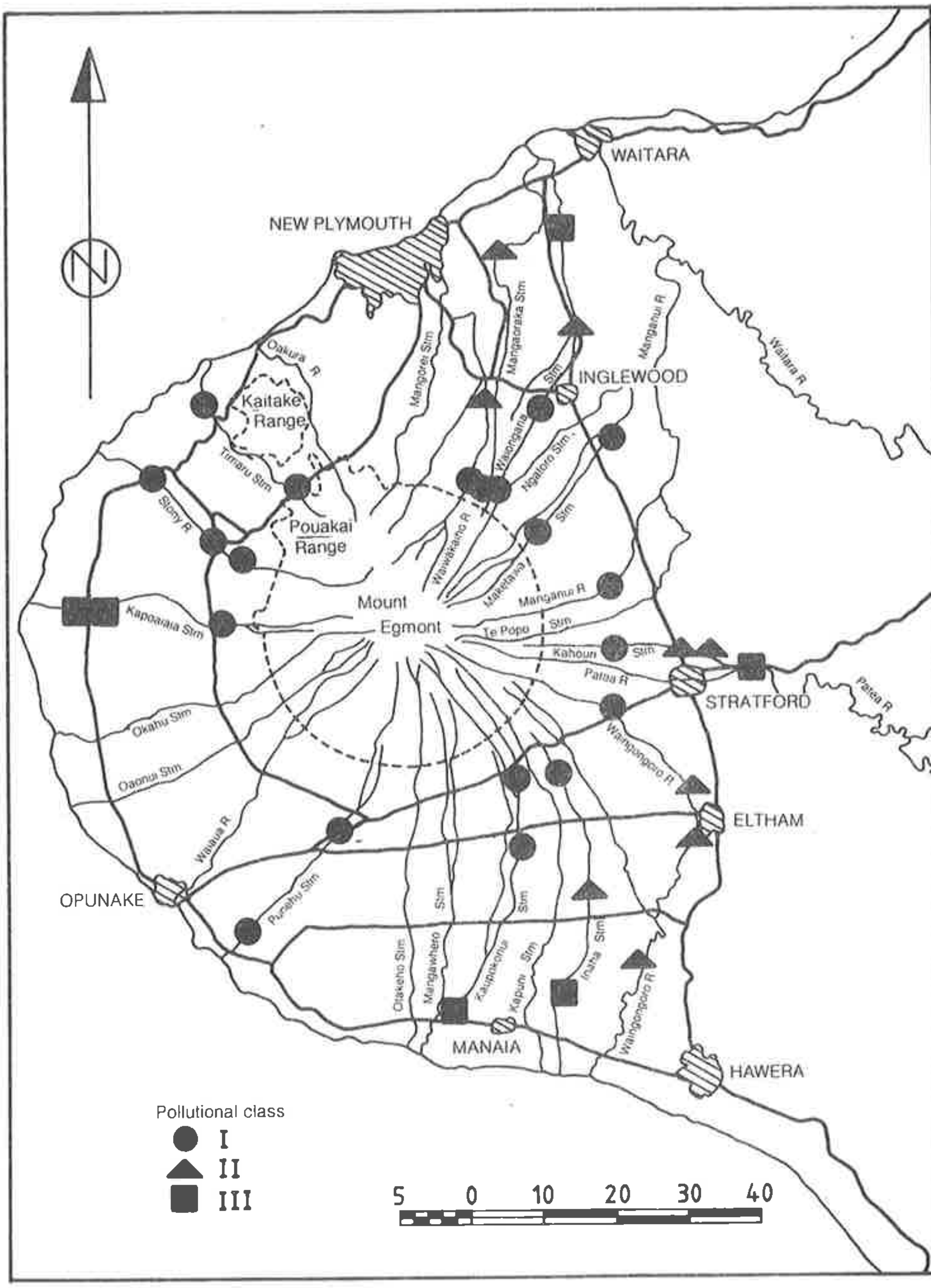

Figure 4: Pollutional classification of ringplain sampling sites based upon MCI values calculated from combined winter, spring and summer samples.

5.2 Taxa characteristic of site groups

Most taxa (34 of 67) were recorded at sites from each of the three site groups (SGI-SGIII). Only 11 taxa (*Ameletopsis, Atalophlebioides, Stenoperla, Megaleptoperla, Acroperla,* Staphylinidae, *Limonia,* Podonominae, *Psilochorema, Hydrochorema,* and *Con'ixia*) were recorded only from site group I but, of these, only *Stenoperla, Megaleptoperla* and *Psilochorema* were recorded from more than 1 or 2 sites on any sampling occasion (Table 4). Even then, these taxa were not widely distributed enough to be useful as indicator taxa when considered alone—although when present they seem to be indicative of clean, undisturbed stream conditions. Similarly, taxa considered characteristic of grossly polluted situations were rare (e.g., Psychodidae site group III, *Chironomus* II and III (Table 4)).

These data support Winterbourn's (1981) contention that most taxa have limited utility as indicators of water quality when considered alone, and his suggestion that a community approach (such as the MCI) would likely prove more worthwhile.

Table 4: Number of stony riffle sites on 13 Taranaki ringplain streams at which taxa were represented for each season at each of three site groups

	Winter			Spring			Summer		
Site Group	I	II	III	I	II	III	I	II	III
Number of Sites	22	7	6	21	6	8	22	6	7
Taxa									
Ephemeroptera									
Ameletopsis	1								
Nesameletus	19	3		18	2	2	21	6	1
Coloburiscus	18	4		19	3	2	18	6	1
Zephlebia	3	1		1	2	1	6	5	
Deleatidium	22	6	4	20	5	6	22	6	4
Atalophlebioides							1		
Mauiulus	7	4		3	3	1	11	6	
Austroclima	12	3		7	4		17	5	
Plecoptera									
Stenoperla	3			6			4		
Megaleptoperla	3			5			6		
Zelandoperla	10			10			14	2	1
Zelandobius	12	6	3	4	5	5	6	3	2
Acroperla	1								
Hemiptera									
Microvelia								1	
Megaloptera									
Archichaulioides	10	5	2	11	3	3	21	5	5
Coleoptera									
Hydraenidae	6			13	1		14	3	1
Hydrophilidae	1							1	
Staphylinidae	1						1		
Elmidae	19	4	4	21	6	3	22	6	5
Ptilodactylidae	2			2		1	3	1	
Dytiscidae									
Diptera									
Limonia	1								
Aphrophila	15	6	4	17	4	6	17	4	4
Eriopterini	10	2	1	9	1		6	1	
Psychodidae						2			1
Tanyderidae							1	2	1
Tanypodinae	1	1		2		1	3	2	3
Podonominae	1								
Maoridiamesa	4	4	4	8	4	8	9	5	5
Orthocladiinae	15	6	6	12	4	8	16	5	7
Polypedilum		1	1	1	1	2		3	
Chironomus			1		1	2		2	2
Tanytarsini		4	3	2	4	5	6	5	6
Ceratopogonidae		1			2	2	2	2	4
Austrosimulium		2	2				7	3	4
Stratiomyidae	1							1	
Empididae	4	2	2	3	2	2	3	3	7
Anthomyiidae	1	1	1					2	4
Tabanidae				1	1				
Trichoptera									
Orthopsyche	4	1		2			3		
Aoteapsyche	13	4	3	18	4	4	20	6	3
Polyplectropus							4	1	1
Hydrobiosis	18	3	3	12	3	5	19	5	4
Psilochorema	7			4			6		
Neurochorema	2	3		5	1		6	4	
Hydrochorema	1								
Costachorema	4	2	1	6	1	1	10	1	1
Tiphobiosis	6		1	1			2		1
Oxyethira	1	1	3			2	5	3	4
Paroxyethira			1						1
Pycnocentria	6	5		3	3	1	5	3	1
Beraeoptera	17	4	3	17	2		18	4	1
Pycnocentrodes	14	5	3	16	5	4	17	4	5
Confluens		1			1		2	1	
Conuxia				1		2			
Olinga	16			13	1		15	2	
Oeconesidae							1	1	
Helicopsyche	12	1		14	1		4		
Triplectides		1							
Crustacea									
Amphipoda		1	1		2			1	1
Oligochaeta	6	3	4	5	3	8	4	3	7
Hirudinea			1						1
Platyhelminthes		1							1
Mollusca									
Latia									1
Potamopyrgus	2	4	1	4	3	4	5	3	4
Physa			3			1	1		
Acarina	1			1	1	1	1		
Nematoda				1		1			
Number of taxa	45	36	27	39	33	30	47	44	37

5.3 Percentage composition of site groups by major taxa

Clean sites (SGI) tend to be dominated by Ephemeroptera and Trichoptera, and grossly polluted sites (SGIII) by Diptera (especially Chironomidae) and Oligochaeta (Table 5). Communities at slightly to moderately enriched sites (SGII) comprised taxa that may be found in both clean and polluted conditions. Under these conditions Trichoptera, Diptera and Ephemeroptera were dominant. These generalisations are well known (Winterbourn, 1981) and tend to corroborate the performance of the MCI at the site group (pollutional class) level.

Table 5: Percentage composition of invertebrate communities by major groups at stony riffle sites in three site groups for combined winter and summer samples

	Site Group					
	I		II		III	
	%	Range	%	Range	%	Range
Ephemeroptera	44.09	(17.91–81.40)	22.76	(0.88–70.26)	0.58	(0–2.15)
Plecoptera	1.93	(0.10–13.12)	1.02	(0–3.49)	0.27	(0–3.22)
Hemiptera	–		0.01	(0–0.10)	–	
Megaloptera	1.50	(0–4.54)	1.16	(0–2.50)	0.61	(0–2.06)
Coleoptera	7.88	(1.22–17.50)	15.71	(0.94–24.59)	1.98	(0–9.1)
Diptera	7.59	(0.40–47.20)	22.76	(1.09–56.39)	51.43	(40.26–62.51)
Trichoptera	36.85	(1.96–67.51)	32.23	(7.61–57.94)	18.70	(0.77–45.00)
Crustacea	–		0.49	(0–4.62)	0.03	(0–0.08)
Oligochaeta	0.07	(0–0.93)	1.73	(0–2.33)	26.10	(0.92–49.35)
Hirudinea	–		–		0.05	(0–0.12)
Platyhelminthes	–		0.02	(0–0.21)	0.01	(0–0.03)
Mollusca	0.08	(0–0.53)	2.10	(0–6.48)	0.23	(0–1.38)
Acarina	0.01	(0–0.12)	0.02	(0–0.17)	0.01	(0–0.09)

5.4 Factors affecting MCI values

5.4.1 Seasonal Variation

MCI values calculated for single seasons, paired seasons and 3 seasons combined and corresponding site ranking orders are presented in Table 6. It should be noted that MCI values presented for combined samples in Table 6 are recalculated values and not mean values for the appropriate seasonal combinations.

Because one use of the MCI is to rank sites in order of biological "quality", it is important to determine whether rank orders determined at different times of year differ significantly. Consequently, Spearmans rank correlation coefficients were calculated for MCI values for all combinations of single season's samples, paired season's samples and three seasons combined (Table 7).

All correlations were significant at the $P < 0.002$ level (34 df) indicating rank orders of sites did not differ significantly with season or any combination of seasonal samples.

Similarly there were no significant differences detected using paired t-tests between MCI values for all combinations of single season's samples, paired season's samples and 3 seasons combined (Table 8). However, of the single seasons samples, MCI values for summer were most like those for the 3 seasons combined ($t = 0.034$, $p = 97.31\%$, 34 df) (Table 8).

The similarity of MCI values obtained for spring samples (data from which were not utilised in allocating scores of taxa) to those for winter and summer is consistent with the lack of seasonal change in taxonomic composition of New Zealand stream communities (Winterbourn, 1981, 1985) and indicates that the MCI can give consistent results. However, application of the MCI to independent invertebrate distributional data sets for other streams in Taranaki and elsewhere in New Zealand, as presented in section 5.7, is required to assess the performance of the MCI.

SITE	WINTER+SPRING+SUMMER		WINTER		SPRING		SUMMER		WINTER+SPRING		WINTER+SUMMER		SPRING+SUMMER	
	MCI	RANK	MCI	RANK	MCI	RANK	MCI	RANK	MCI	RANK	MCI	RANK	MCI	RANK
Kaupokonui A	149	1	154	2	156	2	143	3=	154	1	149	1	148	1
Manganui A	138	2	146	4	143	5=	132	9=	136	5	141	3=	136	7=
Mangaoraka A	137	3	137	10	123	18	148	2	133	9=	140	5	129	13
Stony B	136	4	150	3	133	14	154	1	134	6=	145	2	140	2
Timaru A	135	5=	132	13=	140	9=	132	9=	130	13=	129	10	138	3=
Waingongoro A	135	5=	136	11	137	12=	142	5	133	9=	139	6	138	3=
Maketawa A	134	7	139	8=	144	4	134	7	138	4	134	8	137	5=
Waiwakaiho A	133	8	140	5=	146	3	132	9=	141	2	127	14	133	10
Stony A	132	9	160	1	129	15	139	6	130	13=	141	3=	130	11=
Waiongana A	131	10	139	8=	140	9=	143	3=	134	6=	136	7	136	7=
Kapoaiaia A	130	11	126	21=	162	1	120	21=	134	6=	123	17	137	5=
Waiongana B	128	12=	130	16	142	7	133	8	130	13=	128	11=	135	9
Inaha A	128	12=	133	12	120	21	127	14	129	16=	132	9	124	16
Maketawa B	127	14	132	13=	137	12=	130	12	131	11=	128	11=	130	11=
Punehu A	126	15	140	5=	143	5=	122	17=	140	3	126	15	127	14
Kahouri A	123	16	126	21=	141	8	122	17=	128	18	119	22	126	15
Timaru B	122	17	109	26	122	19=	125	15	119	21=	122	18=	122	17
Stony C	121	18=	140	5=	125	16	128	13	129	16=	128	11=	121	18
Punehu B	121	18=	115	23	104	26	116	24	112	24	121	20=	120	19=
Kaupokonui B	121	18=	128	19=	122	19=	120	21=	123	19	124	16	120	19=
Waingongoro B	119	21	129	17=	113	23	123	16	116	23	122	18=	119	23
Kahouri B	118	22=	129	17=	124	17	121	19=	120	20	121	20=	118	24
Waiwakaiho B	118	22=	132	13=	138	11	110	26	131	11=	113	23	116	25
Inaha B	114	24	103	29	118	22	118	23	109	25	112	24=	120	19=
Waingongoro D	112	25	105	28	110	24	121	19=	106	26	112	24=	120	19=
Waiongana C	109	26	128	19=	106	25	86	31	119	21=	103	28	99	29
Mangaoraka B	108	27	113	24	95	28=	112	25	104	28=	112	24=	107	26
Kahouri C	106	28	106	27	93	30	109	27	104	28=	111	27	104	28
Waingongoro C	104	29	110	25	100	27	103	28	105	27	102	29	105	27
Kahouri D	93	30	86	33	57	34	95	29	76	33	96	30	92	31
Kapoaiaia Bi	92	31	92	31=	95	28=	78	32	92	31	87	32	91	32
Kaupokonui C	91	32	92	31=	92	31	92	30	93	30	91	31	93	30
Kapoaiaia Bii	84	33	93	30	84	32	75	34	88	32	83	33	82	33
Inaha C	76	34	43	35	70	33	76	33	68	34=	73	34	77	34
Waiongana D	67	35	63	34	51	35	51	35	68	34=	65	35	55	35
Mean MCI	117.7		121.0		118.7		117.5		118.2		118.1		117.9	

Table 6: Seasonal and combined seasons MCI values for Taranaki ringplain streams ranked by 3 combined seasons values in order of increasing pollution and compared with single season and paired seasons MCI values and ranks.

Table 7: Spearmans Rank Correlation Coefficients for MCI values for all combinations of single season's samples; paired season's samples and 3 seasons combined.
W = winter, Sp = spring, Su = summer
All correlation coefficients significant at the P<0.002 level (34 df).

	W	Sp	Su	W+Sp	W+Su	Sp+Su	W+Sp+Su
W	×	0.784	0.851	0.899	0.915	0.800	0.865
Sp		×	0.745	0.940	0.768	0.877	0.845
Su			×	0.822	0.958	0.910	0.932
W+Sp				×	0.868	0.892	0.910
W+Su					×	0.916	0.961
Sp+Su						×	0.959
W+Sp+Su							×

Table 8: The results of paired t-tests comparing the differences between MCI values for all combinations of single season's samples; paired season's samples and 3 seasons combined. Lower half of matrix presents percentage probabilities of no significant difference (34 df).
W = winter, Sp = spring, Su = summer

	W	Sp	Su	W+Sp	W+Su	Sp+Su	W+Sp+Su
W	×	0.372	0.613	0.510	0.529	0.577	0.634
Sp	71.09	×	0.205	0.089	0.100	0.150	0.190
Su	54.21	83.84	×	0.135	0.126	0.071	0.034
W+Sp	61.19	92.93	89.33	×	0.012	0.069	0.113
W+Su	59.89	92.03	90.01	99.08	×	0.058	0.104
Sp+Su	56.60	88.15	94.38	94.55	95.37	×	0.042
W+Sp+Su	52.80	84.96	97.31	91.01	91.78	96.64	×

Table 9: Analysis of variance for winter, spring and summer MCI values from 35 sites on the Taranaki ringplain

	df	sum of squares	mean square	$F_{34,102}$
between sites	102	64322.86	630.62	0.180
within sites	2	226.53	113.27	(P=16.4%)
Total	104	64549.39		

Analysis of variance between and within sites (Table 9) demonstrates that there was approximately 248 times more variation between sites than within sites. Only 0.35 percent of the total sum of squares variation was within sites, confirming that samples taken in any of the 3 seasons (viz winter, spring or summer) are likely to provide consistent estimates of MCI. The same is likely to be true also for autumn samples (Winterbourn, 1985; Stark, unpublished data). Spearman's rank correlation analysis was applied also to seasonal and combined-seasonal MCI values for **separate** site groups to test seasonal variability in ranking sites within individual site groups. For the purpose of these analyses site group I comprised 20 sites (MCI 121–149), site group II, 9 sites (MCI 104–119) and site group III, 6 sites (MCI 67–93) based upon combined seasons (i.e., W+Sp+Su) MCI values (Table 6).

Summer MCI rankings were most similar to 3 seasons combined rankings for site group I (rho = 0.788, P<0.001) and site group III (rho = 0.886, P = 0.009) although spring samples (rho = 0.846, P = 0.002) were more similar to combined seasons rankings than summer samples (rho = 0.721, P = 0.014) for site group II.

Of all possible combinations of paired seasons, winter and summer samples provided best rank correlations with 3 seasons combined MCI values for site groups II (rho = 0.913, P<0.002) and III (rho = 0.943, P = 0.002). For site group I any set of paired seasonal MCI values correlated highly with 3 seasons combined values (rho = 0.699–0.830, P<0.002).

The results suggest that summer sampling is likely to provide site ranking lists in best agreement with the "annual" picture for a single annual survey, and that, when sampling is carried out six-monthly, winter and summer samples combined will improve this agreement.

In contrast, significant seasonal variability in biotic indices has been demonstrated clearly in some northern hemisphere studies (Murphy, 1978; Armitage *et al.*, 1983). Armitage *et al.* (1983) found that ASPT differed significantly between spring and summer ($t = 6.87$, $P < 0.001$) and between spring and autumn ($t = 7.45$, $P < 0.001$), and also between all possible pairs of these 3 seasons and between paired seasons and all 3 seasons combined. However, despite significant seasonal variability, Armitage *et al.* (1983) considered that the differences between maximum and minimum ASPT between seasons at each site were relatively small compared with differences between sites. Consequently, they concluded that samples taken in any of the 3 seasons were likely to provide consistent estimates of ASPT.

5.4.2 Sample size

Because series of replicate samples were not available for investigating the effect of successive combinations of replicate samples (i.e., increasing sample size) on MCI accretion, it was decided to test the sensitivity of MCI to deletion of rare taxa. Therefore, taxa represented in winter and summer invertebrate samples by only 1 or 2 individuals were omitted from MCI analyses and the results were compared with MCI values for the complete data set using paired t-tests.

A significiant difference was detected for the comparison of the **percentage changes** in MCI due to omission of rare taxa between winter and summer samples ($t = 2.541$, $P = 0.013$, 34 df). Omission of rare taxa tended to increase MCI values for winter samples by a mean of 2.3 percent (SD8.2) and decrease MCI values for summer samples by a mean of −2.6 percent (SD7.84). Change in MCI resulting from omission of rare taxa was within 10 percent for about 85 percent of both winter and summer samples. Extreme percentage changes of +16.3 percent and −18.6 percent and +12.3 percent and −21.1 percent were obtained for winter and summer respectively. However, for both winter ($t = 0.423$, $P = 0.673$, 34 df) and summer ($t = 0.388$, $P = 0.699$, 34 df) samples no significant difference was detected between MCI values calculated using complete and reduced data sets.

Increases in MCI with omission of rare taxa indicate that the omitted taxa were lower scoring than the average score per taxon for the sample, and conversely decreases were due to omission of higher than average scoring taxa. Polluted sites in swiftly flowing streams with cleaner conditions immediately upstream seem particularly susceptible to large percentage reduction in MCI with the omission of rare taxa [e.g., Kahouri D, −18.6 percent (winter), and −14.7 percent (summer)] and sites in such conditions that experience seasonal variation in effluent loading (e.g., below dairy factories) also may show marked variation in the percentage decrease in MCI [e.g., Waiongana C −1.6 percent (winter) and −17.4 percent (summer)]. The presence in samples of low numbers of higher scoring taxa that have drifted down from upstream may explain this effect. These results suggest that MCI, on average, is relatively independent of sample size, and that the samples collected during the present study [which had means of 14.5 (winter) to 18.6 (summer) taxa and 310 (winter) to 593 (summer) individuals per sample] provided reliable MCI values.

Similarly, Armitage *et al.* (1983) found that the ASPT was relatively insensitive to sampling effort and that an unbiased estimate could be obtained from a single 3 minute kick sample using a 0.9 mm mesh hand-net.

5.5 Relationship of MCI to physical characteristics of sampling sites

The physical characteristics of a site have a marked effect on the fauna present at that site and the development of numerical relationships between the MCI and physical features of sampling sites should be attempted. The value of predicting MCI values from physical data is that it becomes possible to compare observed MCI (MCI_{obs}) values with predictions (MCI_{pred}) and then attempt to explain any discrepancies. If, for example, MCI_{obs} is lower than MCI_{pred} it probably is due to deterioration of water quality (i.e., pollution) (Armitage *et al.*, 1981).

Furthermore, since unpolluted watercourses may support a range of macroinvertebrate community types, the naturally achievable MCI inevitably will vary between sites or regions. For example, substrate particle sizes generally decrease downstream, and substrate type has a marked effect on invertebrate community composition. Therefore, it probably is unrealistic to expect that MCI values in the lower reaches of an unperturbed stream will be as high as those from nearer the headwaters. Winterbourn (1981) stated that an appreciation of the kind of undamaged (i.e., healthy) community that can be expected to exist under a particular set of conditions was required before an assessment could be made of stream damage on the basis of its benthic macroinverebrate community.

Because combined winter and summer samples best represent the annual MCI value, these are used to give an example of a relationship between MCI and a physical variable (viz site altitude) for Taranaki ringplain streams. Unperturbed sites were selected from the data set [all sites with site codes ending in 'A' (except Stony A, Kaupokonui A and Kahouri A) and including Maketawa B, Waiongana B, Timaru B, Kaupokonui B, Punehu B and Waingongoro B] and regressed against site altitude (Fig. 5).

The relationship obtained

$$MCI = 116.054 + 0.048A \qquad R^2 = 0.609$$

where A = site altitude (m above msl)

indicates that 60 percent of the variability in MCI, for the subset of data from unperturbed sites, may be explained in terms of the linear relationship with altitude. The slope of this regression line is not significantly different from zero but since the relationship is used strictly in a descriptive sense (i.e., as a prediction equation) and no statistical inferences are made, it is of little concern. In this example, altitude is assumed to be related to the length of the river below the Egmont National Park boundary, that flows through farmland and hence receives organic enrichment. Distance by river from the park boundary most likely would be a more reliable, though less easily estimated, physical variable.

From the above equation, one could expect MCI values in stony streams at the Egmont National Park boundary (*ca.* 500 m, above msl) and near the coast (0 m, above msl) to be 140 $\pm$ 10 (i.e., 130–150) and 116 $\pm$ 10 (i.e., 106–126), respectively. In each case, 99.9 percent confidence limits and intervals are given. Any observed MCI values falling below these predictions most probably experience significant pollution and could warrant further investigation. It is not suggested that a similar relationship would be of widespread application but it is important to realise that one should not **necessarily** expect lowland reaches (even of unpolluted streams) to realise the same MCI values as their upland tributaries.

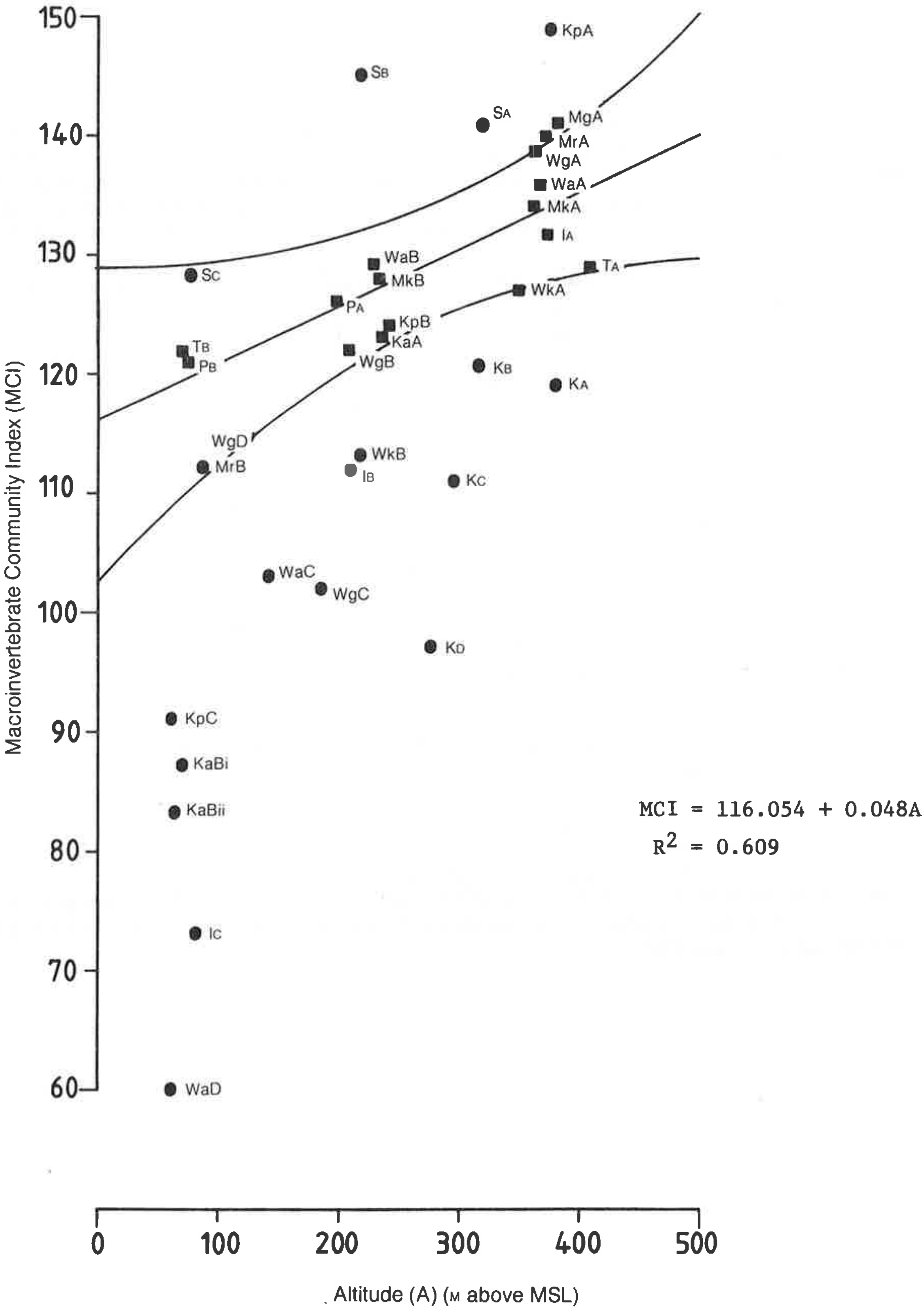

Figure 5: Relationship between MCI and site altitude for streams on the Taranaki ringplain based upon combined winter and summer invertebrate samples. Sites included in regression are indicated ■. 99.9 percent confidence limits about the regression line are shown also.

5.6 Relationship of MCI to water quality

Limited spot measurements of water quality variables were available for the biological sampling sites studied as part of the Taranaki Ringplain Water Resources Survey (Taranaki Catchment Commission 1984a, b). Invertebrate community composition reflects the water quality variables and the MCI has been shown to exhibit little seasonal variation (section 5.4.1). However, since physico-chemical variables may show marked seasonal or diurnal variation it is likely that correlation of spot measurements with MCI values will produce unsatisfactory results. Specific investigations on selected streams, involving intensive (preferably continuous) water quality and hydrological monitoring prior to invertebrate sampling, are likely to be of most value for investigation of these relationships. Considering the work involved and its cost, it is hardly surprising that progress has been slow in this area.

By this means one may be able to identify which water quality variables affect stream macroinvertebrate communities and cause discontinuity in MCI values such as that depicted on Figure 6.

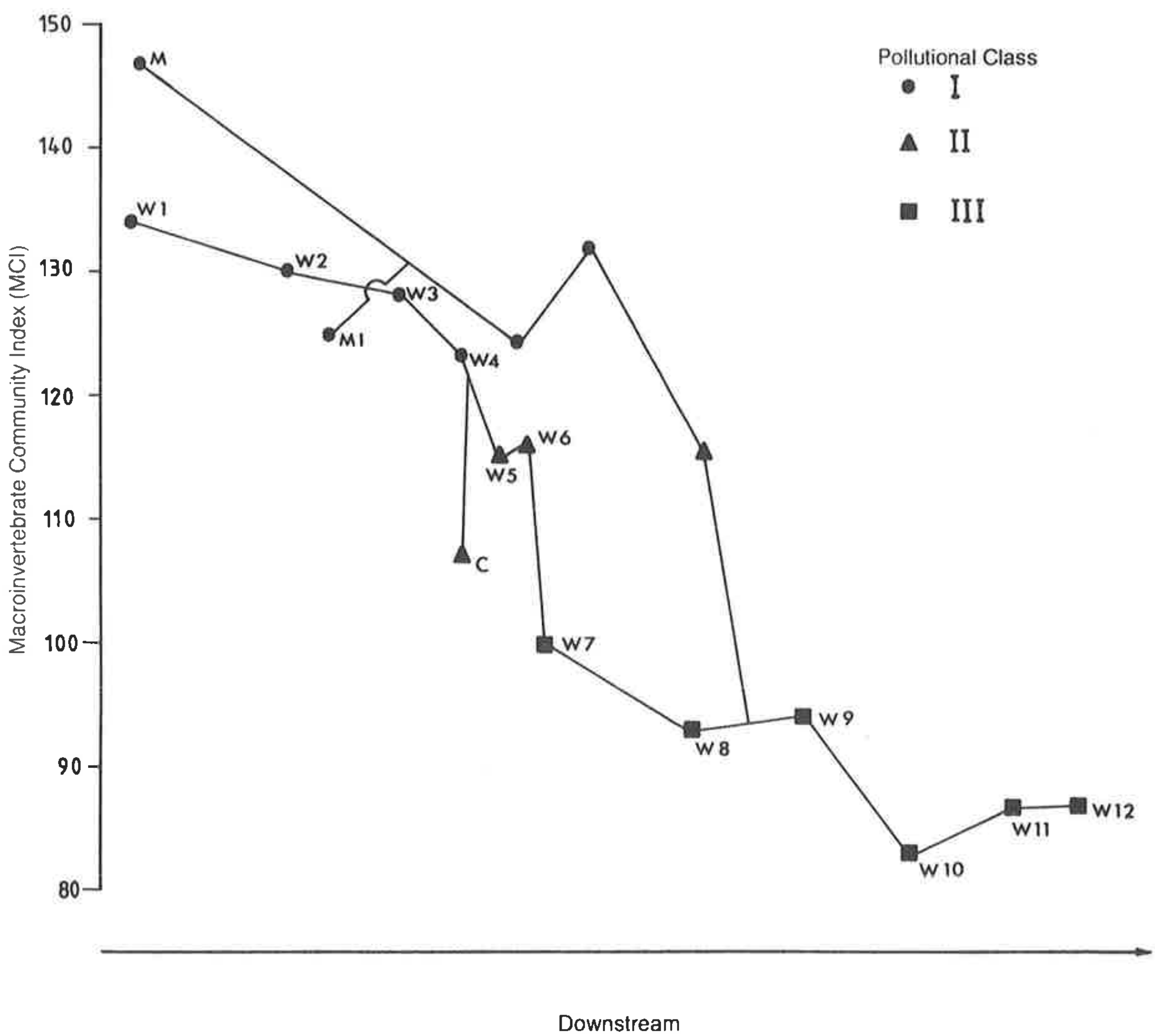

Figure 6: MCI values for selected sites on the Waingongoro Stream (W), Mangatoki Stream (M), Mangatoki-iti Stream (MI) and Climie Stream (C) in the Waingongoro catchment (20–21 July 1983).

5.7 Application of MCI to data other than those collected during the Taranaki Ringplain Water Resources Survey

5.7.1 Introduction

In this section, invertebrate distribution data sets other than those collected as part of the Taranaki Ringplain Water Resources Survey are utilised to assess the performance of the MCI and its suitability for application in other areas of New Zealand. Existing data from the following sources have been examined:

Hirsch (1958)
Winterbourn, Alderton and Hunter (1971)
Winterbourn & Stark (1978)
Marshall & Winterbourn (1979)
Stark (1982)

as well as data from repeat surveys of selected sites on the South Branch (Waimakariri River) and the Kaiapoi River on 1 March 1984 by R. D. Pridmore, J. D. Stark and M. J. Winterbourn. Additional taxa scores are listed in Table 10.

Performance of the index is assessed by noting whether or not results of MCI analyses are consistent with interpretations presented by the original investigators. For the purposes of this evaluation it is assumed that these interpretations represented a true assessment of stream quality.

Table 10: Scores allocated to invertebrate taxa, which were not recorded in the Taranaki ringplain biological survey, for use in calculation of MCI values

Ephemeroptera		Crustacea	
Ichthybotus	8	Ostracoda	3
		Paratya	5
Hemiptera		*Paranephrops*	5
Sigara	5	Isopoda	5
Odonata		Mollusca	
Xanthocnemis	6	*Gyraulus*	3
		Ferrissia	3
Diptera		Sphaeriidae	3
Paradixa	4		
Syrphidae	1	Collembola	6
Lobodiamesa	5		
Ephydridae	4		
Trichoptera			
Hydrobiosella	9		
Synchorema	6		
Hudsonema	6		

5.7.2 Taranaki Streams

Kaupokonui Stream

Figure 7 depicts MCI values for data collected during March 1957 by Hirsch (1958). At that time, discharges into the Kaupokonui Stream included two cheese factories (unknown waste composition, believed to be mostly wash-water), domestic sewage (500 persons), lactose-powder factory (5,000 population equivalent) and a further dairy factory (unknown discharge composition). Hirsch (1958) found that the wastes from the lactose-powder factory exceeded the self-purification capacity of the stream over a distance of several kilometres, whereas the other sources had little effect. Immediately prior to the March 1957 survey, pollutional conditions below the lactose-powder factory had been reported to be the worst ever observed.

Hirsch (1958) considered the fauna at station 10 in the Kaupokonui Stream (immediately downstream of the Dunn's Creek confluence) to be indicative of partial recovery and that by station 14 almost complete recovery had occurred. On Dunn's Creek, Hirsch (1958) found that effluent from the cheese factory near the headwaters produced a septic zone, whereas waste from a similar factory downstream (where the stream flow was much greater) had little effect.

MCI values calculated for these data (Figure 7) generally are consistent with Hirsch's (1958) conclusions. Only the most upstream sites on the Kaupokonui Stream (site 1) and Dunn's Creek (site 18) could be regarded as unpolluted (MCI > 120). MCI values less than 100 occurred below most of the dairy factory outfalls, indicating moderate to gross pollution. MCI values indicate some improvement in the lower reaches of the Kaupokonui Stream (sites 10–17 vs sites 7–8, Figure 7) but it must be remembered that MCI values as high as these observed in upland situations (say 125+) generally will not be realised in the lower reaches (see Section 5.5)

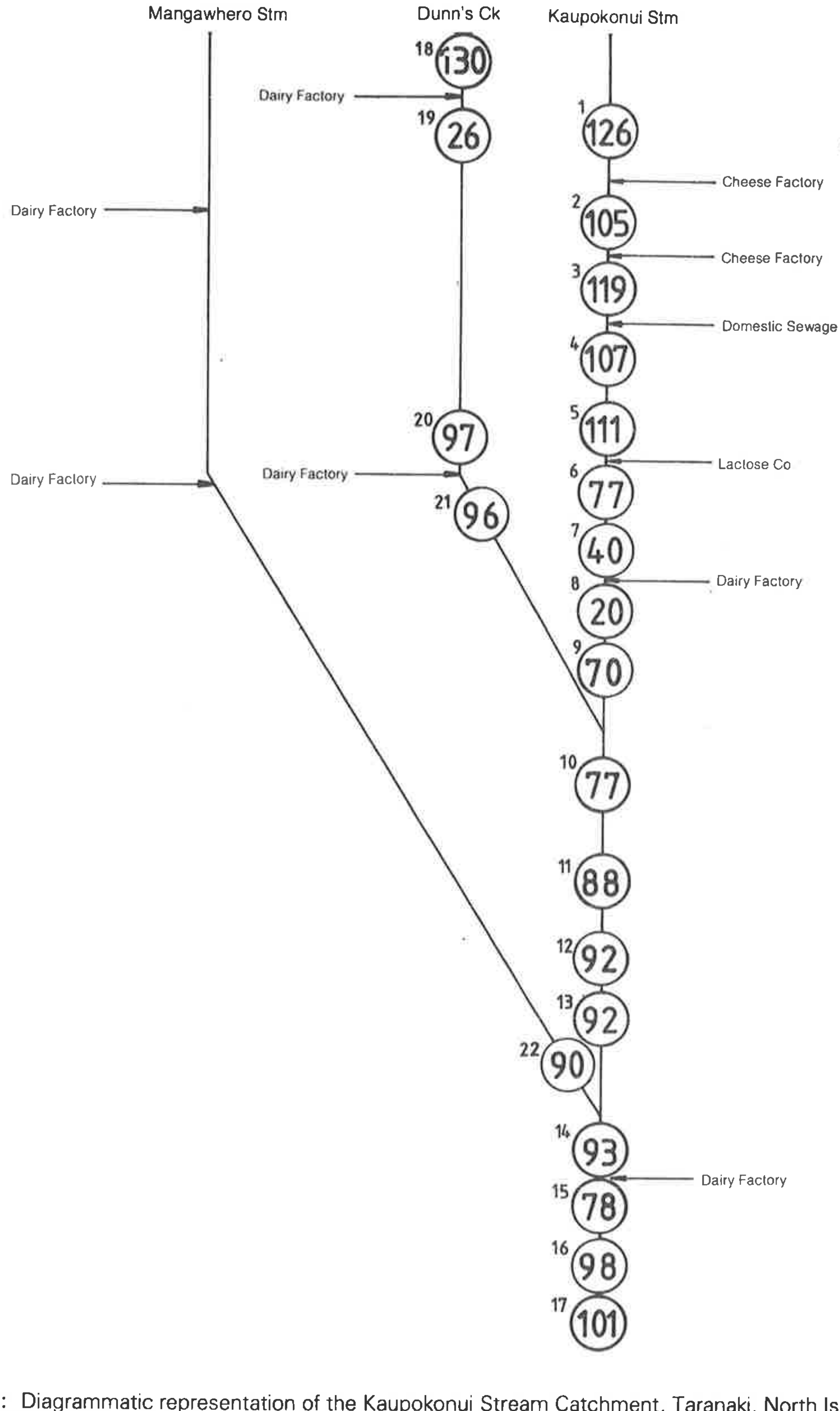

Figure 7: Diagrammatic representation of the Kaupokonui Stream Catchment, Taranaki, North Island, New Zealand showing main pollution inputs and MCI values for 22 sites. (March 1957). Data and site numbers from Hirsch (1958). (NB not to scale).

Patea River

Eight sites on the Patea River, Taranaki were sampled during July/August and October 1981 (Stark, 1982) (Figure 8). Triplicate foot-kick samples were collected from stony riffle sites (except site P6 on 21 July 1981 when samples were collected from a silty region near the river bank because the riffle area was not accessible).

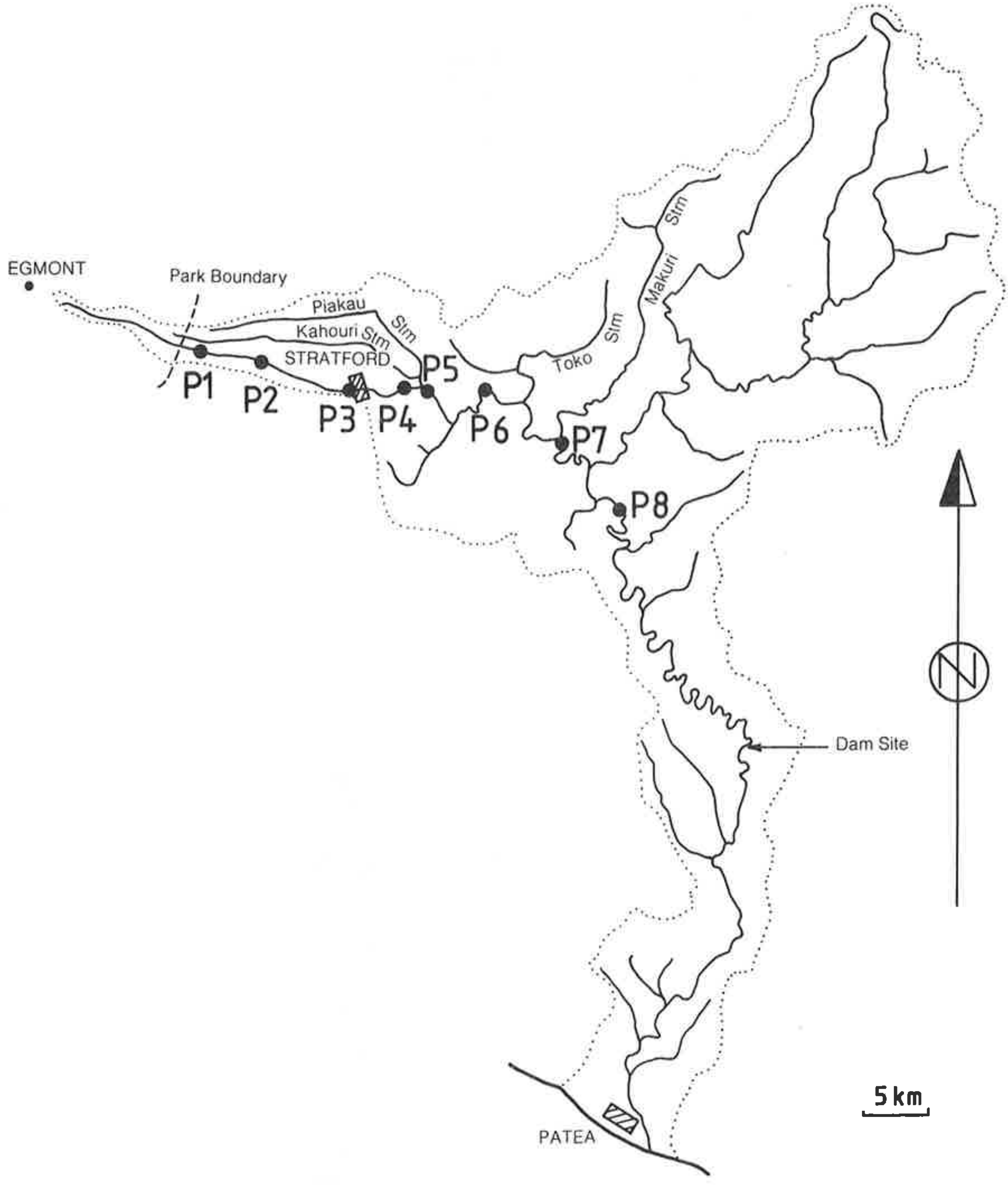

Figure 8: Map of the Patea River catchment showing invertebrate sampling sites on the Patea River (P1–P8).

Percentage invertebrate community compositions are depicted in Figure 9 indicating a major change from a mayfly/caddisfly dominated community (sites P1–P3) to one dominated by dipteran larvae (especially chironomids), oligochaete worms and/or amphipod crustaceans further downstream.

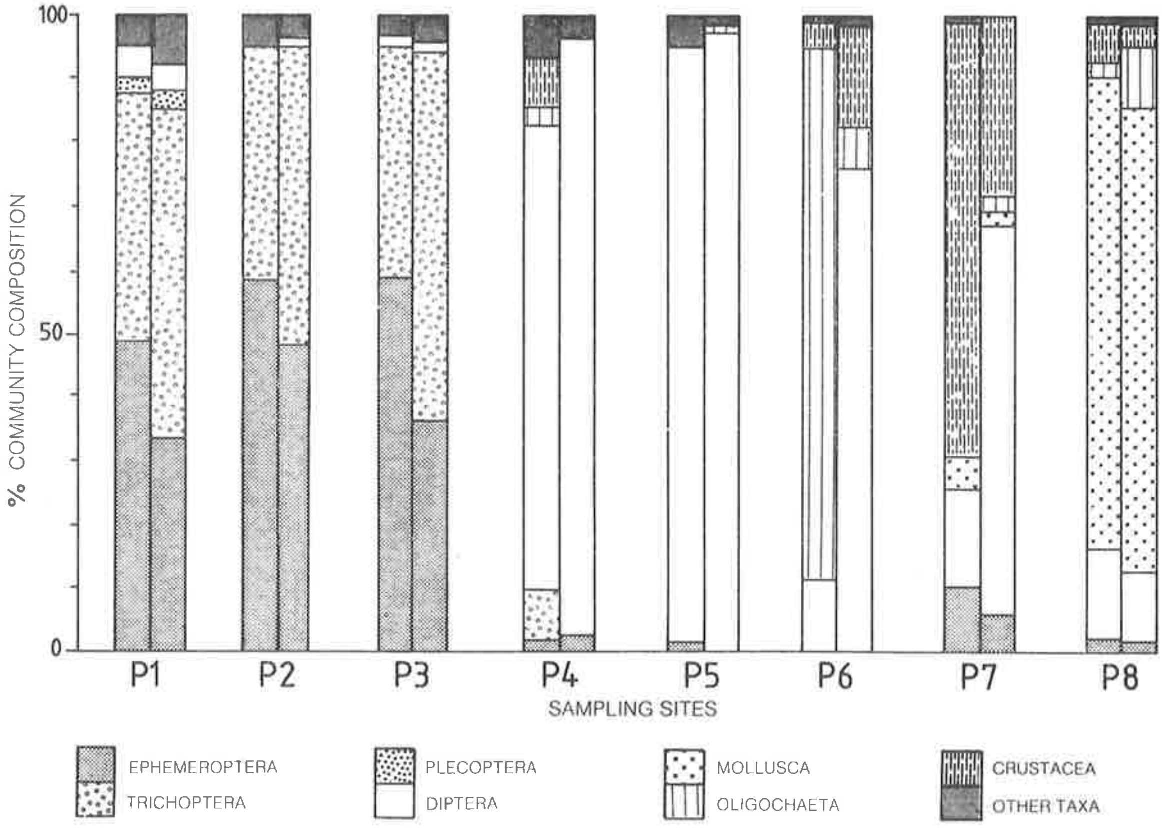

Figure 9: Percentage composition of invertebrate communities by major groups at selected sites in the Patea River. The first bar at each site is for July-August and the second for October 1981. See Figure 8 for locations of sites. Taxa shown only when > 1 percent of community composition.

Dominant taxa (Table 11) found at sites P1–P3 above Stratford are characteristic of unpolluted stream conditions whereas communities found below Stratford, which were dominated by orthocladine chironomid larvae, are typical of organic enrichment (Winterbourn, 1981). Differences in community composition between times at site P6 almost certainly were related to substratum type—a riffle community dominated by chironomids and amphipods would most likely have been present also in July/August as in October.

The invertebrate fauna at the two most downstream sites (P7–P8) was dominated by species that are characteristic of larger, slow-flowing rivers (Table 11).

MCI analyses (Table 12) indicate that the sites above Stratford (P1–P3) could be classed as clean and unperturbed (MCI > 120), but between sites P3 and P4 stormwater from Stratford, dairy factory effluent and municipal oxidation pond effluent entered the river and a marked decrease in MCI occurred. The Kahouri Stream entered the Patea River between sites P4 and P5 and had only slight impact on MCI values. According to MCI values, the Patea River below Stratford could be classed as subject to the effects of moderate organic enrichment. These conclusions are consistent with those of Stark (1982).

Table 11: Invertebrate taxa contributing greater than 10 percent to community composition at each sampling site in the Patea River (locations of sites are given in Figure 8)

Site	July-August 1981 Taxon	%	October 1981 Taxon	%
P1	*Deleatidium* sp.	42.1	*Beraeoptera roria*	36.5
	Helicopsyche albescens	16.4	*Deleatidium* sp.	20.0
	Beraeoptera roria	15.9	*Coloburiscus humeralis*	13.2
P2	*Deleatidium* sp.	34.1	*Deleatidium* sp.	25.4
	Coloburiscus humeralis	21.3	*Beraeoptera roria*	23.4
	Helicopsyche albescens	16.4	*Coloburiscus humeralis*	21.3
	Olinga feredayi	15.3	*Helicopsyche albescens*	10.6
	Beraeoptera roria	11.1		
P3	*Deleatidium* sp.	35.2	*Helicopsyche albescens*	24.0
	Coloburiscus humeralis	20.7	*Deleatidium* sp.	21.3
	Helicopsyche albescens	19.8	*Beraeoptera roria*	17.4
	Beraeoptera roria	11.0	*Pycnocentrodes aureola* } *Coloburiscus humeralis*) }	11.1
P4	*Cricotopus/Syncricotopus* spp	62.0	*Cricotopus/Syncricotopus* spp	75.0
			Maoridiamesa sp.	13.1
P5	*Cricotopus/Syncricotopus* spp	90.1	*Cricotopus/Syncricotopus* spp	94.1
P6	Oligochaeta	81.3	*Cricotopus/Syncricotopus* spp	69.4
	Cricotopus/Syncricotopus spp	10.9	*Paracalliope fluviatilis*	16.0
P7	*Paracalliope fluviatilis*	69.0	*Cricotopus/Syncricotopus* spp	60.8
	Oxyethira albiceps	10.5	*Paracalliope fluviatilis*	27.9
P8	*Potamopyrgus antipodarum*	72.5	*Potamopyrgus antipodarum*	75.2

Table 12: MCI values for 8 sites in the upper Patea River for July/August and October 1981

SITE	P1	P2	P3	P4	P5	P6	P7	P8
July/August	144	130	129	98	100	80	66	74
October	135	137	126	92	85	84	73	94

5.7.3 Other North Island Streams

Manawatu and Oroua Rivers

In March 1957 the Manawatu River received a number of domestic sewage inputs and freezing works/dairy factory discharges. According to Hirsch (1958) the sewage discharges had no detectable effect on benthic macroinvertebrate communities although the sewage discharge from Palmerston North (35,000 population equivalent) did stimulate the growth of sewage fungus. The freezing works/dairy factory discharges (150,000 population equivalent) below station 3 ''partially affected'' the fauna at station 4 but the ''fauna recovered a short distance downstream'' (station 5).

However, in the Oroua River, which had approximately one-sixth of the flow of the Manawatu River, marked changes were observed in macroinvertebrate community composition due to the effects of domestic sewage (183,000 population equivalent) and, to a lesser extent, freezing works discharges.

Hirsch (1958) concluded that

''. . . self-purification of the Oroua River was markedly exceeded, wastes of a similar polluting strength did not cause serious . . . effects on the stretch of the Manawatu River sampled because of the greater dilution afforded.''

Changes in MCI downstream in both rivers (Figure 10) are consistent with Hirsch's explanations.

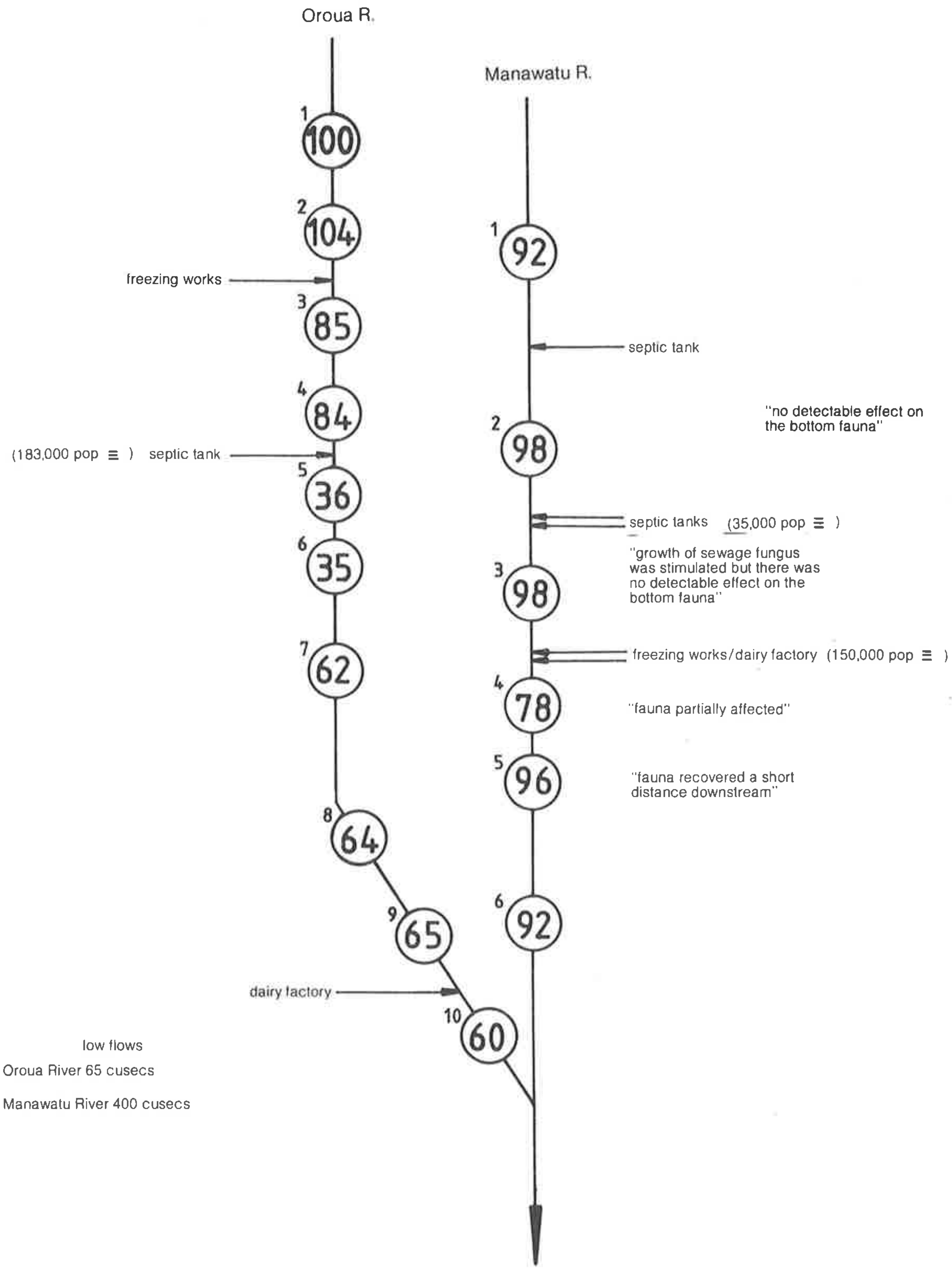

Figure 10: MCI values for sixteen sites on the Manawatu and Oroua Rivers (March 1957). Data from Hirsch (1958). (Figure not to scale).

5.7.4 South Island Streams

Cam River

Hirsch's (1958) survey of the Cam River, into which effluent from a candied peel factory and a small septic tank was discharged, revealed little change between sites in species presence/absence but, nearly 14 years later, data collected by Winterbourn *et al.* (1971) showed considerable reduction in mayfly and caddisfly diversity at impacted sites. Although Winterbourn *et al.* (1971) stated that only localised minor changes were evident below the outfall in their study and that the situation was similar to that recorded by Hirsch (1958), I believe that, in this case, the MCI approach has revealed a more realistic picture. Namely that there was little change at the control sites between times but that the effluent discharge had greater impact in January 1971 than April 1957. Part of this difference could have been related to the time of year of sampling—environmental effects of an organic discharge may be expected to be worse in January than in April—although as shown previously (Section 5.4.1) there is little seasonal variability in MCI values unless there is seasonal variability in effluent discharge quality/quantity.

Northbrook Drain

Changes in fauna at Station 1 between 1957 and 1971 were considered by Winterbourn *et al.* (1971) to be a result of a change in substratum from shingle/sand/detritus to clay/mud/sand/detritus. Below the sewage effluent input at station 2 Winterbourn *et al.* noted "a possible improvement in water quality" but that little difference between times was evident at more downstream stations (except station 6). At station 6 (Table 13) increased deposition of fine sediment (unknown cause) was implicated in causing the change in benthic macroinvertebrate community structure.

These data indicate the importance of knowledge of substratum type (especially if sampling sites cannot be selected with similar substrata). In this case, MCI analyses (Table 13) are consistent with changes in pollutional status and substratum that have occurred between times.

Kaiapoi River (North Branch)

Hirsch (1958) considered that the fauna present in the Kaiapoi River above pollution was varied (station 1) but at station 3 below the fellmongery and dairy shed discharges the fauna had been "markedly restricted" by pollution. Further downstream at station 4 the fauna still was considered indicative of pollution although improved relative to station 3. This pattern is evident also in MCI values but it should be noted that the MCI of 88 for Hirsch's station 2 (H2 on Figure 11) is lower than expected due to the presence of organic detritus in the sand/shingle substratum. The substrata of all other sites comprised sand and/or shingle only.

Winterbourn *et al.* (1971) found that increased deposition of fine organic material from the fellmongery had changed the nature of the substratum downstream and this, together with an increased supply of nutrients to the stream, was responsible for a change in the composition of the fauna. The effects of organic pollution were considered greater in 1970–71 than in 1957–58. Furthermore, Winterbourn *et al.* found that there had been changes in the composition of bottom faunas of the Ohoka Stream and the Cust Main Drain since 1957. These changes were of a kind to be expected through gradual enrichment from farmland runoff (perhaps due to increased use of fertilisers in the catchment).

The survey by Winterbourn and Stark (1978) followed installation of an effluent treatment system on the fellmongery and revealed a dramatic improvement in stream conditions. Macroinvertebrate communities were described as "characteristic of clear, flowing, lowland waters supporting abundant submerged vegetation and/or a substrate of sand, silt and gravel or coarse detritus."

The present study (March 1984) since the fellmongery has closed down, is suggestive of further improvement in stream conditions. The major pollution source at present is a dairy shed discharge, the effects of which probably were masked previously by the fellmongery discharge.

Interpretations based upon MCI analyses are consistent with the above (Figure 11).

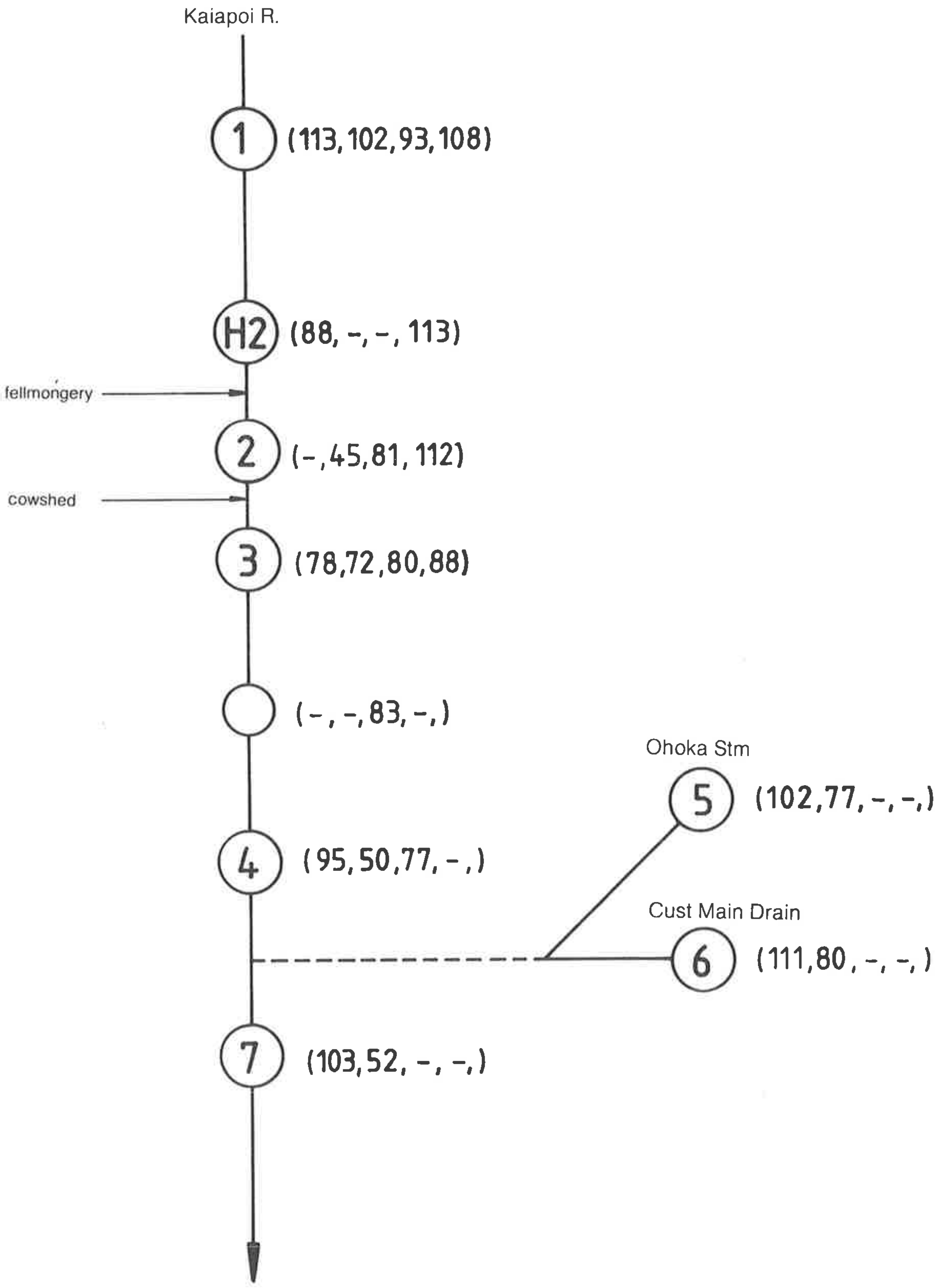

Figure 11: MCI values for eight sites on the Kaiapoi River system. Site numbers (in circles) after Winterbourn *et al.* (1971). MCI values are given for the following dates in parentheses:
(Feb 1957, Nov-Dec 1970, Dec 1977, Feb 1984).
Data from Hirsch (1958), Winterbourn *et al.* (1971), Winterbourn and Stark (1978) and present study.

Table 13: MCI values for various streams in the South Island, New Zealand.
Data from Hirsch (1958), Winterbourn *et al.* (1971), Winterbourn & Stark (1978), Marshall and Winterbourn (1979) and present study.
Sites are numbered consecutively downstream and arrows represent entry of point-source organic pollution.
Data from stony/sandy samples only included—samples from weed beds excluded.

Stream Date	Site Number 1	2	3	4	5	6	7	8	9
Cam River									
April 1957	100	↓98	102						
January 1971	105	↓58	66						
Northbrook Drain									
February 1957	101	↓64	81	100	90	102	113		
January 1971	72	↓80	77	79	-	76	105		
South Branch Waimakariri									
March 1957	96	103	↓88	91	92	↓33	20	20	
December 1970	91	124	↓ -	-	105	↓20	-	42	
March 1984	-	-	98	-	-	↓20	-	-	
Leeston Drain									
One year's data 1972–73	77	64	81	↓66					
Mataura River									
April 1957	113	94	↓94	88	↓77	84	97	↓93	85
Makarewa River									
April 1957	76	↓64	71						

Waimakariri River (South Branch)

In March 1957, Hirsch (1958) concluded that station 1 supported a normal clean-water fauna even though it was located in an area of shingle bottom which had heavy algal growth. Station 3 was considered mildly polluted, being characterised by an increase in numbers and kinds of pollution-tolerant organisms with sensitive species still present. A small drain that received effluent from a soap factory entered the South Branch between Stations 2 and 3. Station 7 was considered badly polluted by effluent from two freezing works and a wool scour.

Winterbourn *et al.* (1971) concluded that the effects of organic pollution were greater in December 1970 than in March 1957 as they found up to 30 fold increases in densities of oligochaetes and *Chironomus zealandicus*. However, there was little change in community taxonomic composition and consequently MCI analyses would not detect the change. Nevertheless, it is evident that gross pollution of station 6 occurred in both March 1957 and December 1970 and there is no evidence to suggest that conditions at this site have improved subsequently (March 1984) (Table 13).

Leeston Drain

One year (17 sampling occasions) of benthic invertebrate sampling from January 1972 to January 1973 was undertaken by Marshall and Winterbourn (1979). MCI values were calculated from complete species lists collected from each site during this period. Note that in this discussion, site numbers increase downstream; cf. upstream in Marshall and Winterbourn (1979). The most upstream station (1) had a gravel/pebble substratum with encrusting algae and small patches of macrophytes. At station 2, 1.8 km downstream, a layer of fine sand and mud covered most of the coarser bed sediments. Rooted macrophytes were present and, in summer these were covered by filamentous algae.

At station 3, a thick layer of algae occurred on surface sediments during most of the year and patches of macrophytes were present on stable substrata.

Station 4 (75 m downstream of station 3) was situated 50 m downstream of a discharge of dairy shed washings.

Stations 2 and 4 were considered by Marshall and Winterbourn (1979) to be nutrient enriched relative to stations 1 and 3. MCI values (Table 13) are consistent with this interpretation.

Mataura River (Southland)

Hirsch (1958) listed effluent entry points beween stations 2 and 3 (Gore domestic sewage, abattoir, by-products factory, fellmongery), between stations 4 and 5 (Mataura sewage, meat and freezing works, paper mill) and between stations 7 and 8 (Wyndham sewage, lactose powder factory). The river was large and deep and sampling was confined to marginal shingle areas.

Hirsch (1958) concluded that the wastes entering the river at Gore and Wyndham had little effect, whereas the greater volume of wastes discharged at Mataura caused partial pollution damage. Once again, MCI analyses (Table 13) are consistent with this interpretation.

Makarewa River (Southland)

Hirsch (1958) sampled three sites on the Makarewa River. Station 1 was located above a discharge of partially treated effluent from a freezing works, station 2 about 230 m downstream and station 3 approximately 5 km downstream of the discharge. The river was deep and sluggish with a substratum of sand/shingle and silt with abundant aquatic weeds.

Hirsch (1958) considered the fauna less varied above the discharge than in the Kaiapoi River and although stations 2 and 3 (below the discharge) were similar to site 3 in the Kaiapoi River he was not clear whether the same degree of pollution damage had occurred or whether the pollution was of a lesser degree (as at station 4 in the Kaiapoi River). In terms of a percentage reduction in MCI compared with control site values, MCI analyses support the latter hypothesis.

MCI values for the Makarewa River indicate pollutional damage at station 2 and marked recovery at station 3. The MCI value for the control site (station 1) was lower in the Makarewa River (Table 13) than in the Kaiapoi River (Figure 11) presumably due to substratum differences (or regional differences in MCI calibration).

6 Discussion

The Macroinvertebrate Community Index proposed in this paper has produced a site ranking list and site groupings for stony-riffle sites from streams on the Taranaki ringplain. Both the ranking and groupings are consistent with subjective assessment of water quality, and show no significant seasonal variability. Application of the MCI to data sets collected from elsewhere in New Zealand produced interpretations consistent with those based upon more traditional quantitative and descriptive analyses.

The fact that New Zealand stony streams possess a nucleus of common taxa (in addition to taxa with geographically restricted distributions) (Winterbourn *et al.* 1981) is likely to facilitate the process of extending the use of the MCI to other parts of the country. Most of these common taxa have been encountered during the present investigations and scores for MCI analysis allocated. Although many of the widely distributed taxa (and others) that are characteristic of most unmodified streams contributed more to invertebrate community composition of unperturbed streams than enriched streams, many such species can tolerate a broad range of physical and chemical conditions (Winterbourn, 1981) and may be found also in moderately enriched streams. This confirms Winterbourn's (1981) contention that most taxa have limited utility as indicators of water quality when considered alone.

Winterbourn (1981) stated that:

> "although the nature of benthic invertebrate communities varies in relation to physical, chemical and other biotic factors, distinct communities of **highly predictable** composition cannot be defined. Rather, gradual changes in composition and relative abundances of species occur in response to environmental changes." (My emphasis).

This contention is supported by data collected from Devils Creek near Reefton in the South Island (Cowie, 1980) and during the Taranaki Ringplain Water Resources Survey (Taranaki Catchment Commission, 1984a). Consequently, it is unreasonable to expect that any index or classification system based upon assessment of invertebrate community composition necessarily will produce distinct and unambiguous site groupings, which then may be considered characteristic of a number of classes of pollution. Inevitably, some subjectivity will be required in order to delimit site groups. Data on invertebrate community compositions, known point-source discharges, land use types or water chemistry may be utilised in order to aid this process. Although in the present study, site groups were divided at MCI values of 120 $\pm$ 5 (I/II) and 100 $\pm$ 5(II/III), these values should not be regarded as fixed. Further work is required to assess whether or not these divisions have widespread applicability.

Price (1978) *in* Mason (1981) listed the following features that a biological system requires to be suitable for use in monitoring:

1 the presence or absence of an organism must be a function of water quality rather than of other ecological factors;
2 the system must assess water quality reliably, be expressible in a simplified form and yet be sufficiently quantifiable to allow for comparison;
3 the assessment should relate to water quality conditions over an extended period, rather than just at the time of sampling;
4 it is often important that the assessment should relate to the sampling site rather than to the watercourse as a whole;
5 sampling, sorting, identification and data processing should be as simple as possible, involving the minimum of time and manpower.

The MCI meets these requirements well although special care must be taken to ensure that between-site variability in physical characteristics (e.g., substratum type, current velocity, water depth, degree of shading) is minimised so that changes in community structure are related primarily to changes in water quality. To this end, sampling should be undertaken in stony riffles where faunas present are most likely to show an obvious response to changing conditions (Hynes 1960). Often, however, there are differences between sampling sites and, in such cases, more detailed description/measurement of physical features is necessary so that this can be considered when interpreting MCI values. Artificial substrates (e.g., Hester and Dendy, 1962; Hughes, 1975) sometimes may be used to good effect to minimise substratum variability. Among other advantages of artificial substrates are that they may be used at sites which cannot be sampled effectively by other methods. Also, between-sample variability may be reduced and this makes comparison between sites easier. On the other hand, the sample may not be representative of naturally occuring communities at the site (although this is not always important), there may be selective colonisation, and comparisons with other sampling techniques may be difficult (Mason, 1981). Furthermore, artificial substrates require a colonisation period of at least 6–10 weeks in the river and during this time they may be subject to vandalism and loss during floods. The need for a long colonisation period reduces the practicability of using artificial substrates in compliance monitoring—where substrates must be removed frequently or following spills of toxic substances.

6.1 Uses of the MCI approach

MCI values may be used by water managers to rank sites (or rivers) in order to provide a (biological) basis for management decisions regarding, for example, location of abstraction/discharge points or priorities for conservation.

Synoptic surveys may be conducted where invertebrate samples are collected from sites distributed down a river (or throughout a catchment) with particular attention paid to above and below effluent discharges, abstractions or confluences with tributaries. Discontinuities in MCI values then may be subjected to more intensive biological/chemical investigations (if necessary) to determine cause/effect relationships and remedial action may be implemented via, for example, water right procedures. This approach is perhaps the most cost effective way of obtaining an overall perspective of water quality throughout a catchment(s), focussing on areas that require attention and, at the same time, providing preliminary biological resource documentation.

MCI values over time, and their corresponding statistical behaviour, have a potential use in monitoring impacts of effluent discharges on downstream biological communities. Currently, most water right conditions are written around chemical limits which, while useful for operating an effluent treatment system, may bear little relation to the health of the downstream biological community. Although it is recognised that much more work needs to be done in relating chemical levels of effluent discharges to downstream biological communities, the instream MCI could be used as a compliance monitoring check—is the biological community desired being achieved/maintained? If not, the chemical levels may need adjusting. The chemical levels then can be used for operating the effluent treatment system, and changes in the MCI values downstream can indicate the effectiveness of effluent discharge management.

6.2 Suggestions of further research

Further research is required to extend the geographic range of the MCI, primarily, by scoring taxa that were not encountered during the present study. Investigations to date suggest that the index will prove useful in stony streams throughout New Zealand. For example, application of the technique to data collected by Hirsch (1958), Winterbourn *et al.* (1971) and Winterbourn and Stark (1978) for streams and rivers of the lower Waimakariri River system has produced interpretations largely consistent with those of the above investigators. However, it is possible that the index will need to be calibrated for a given river, catchment or geographic region, either to improve its sensitivity or because site groupings considered characteristic of different classes of pollution (e.g., unpolluted or mild/moderate/gross pollution) may be delimited at different MCI values in different places. Because, for example, MCI pollutional class divisions established for Taranaki ringplain streams (Section 5.1) do not seem to apply to North Canterbury streams (Section 5.7.4), it is likely that intensive physicochemical and biological study of a few selected streams throughout New Zealand will be of most value in deriving relationships between physical, chemical and biological characteristics of streams. Widespread stream surveys where data from throughout New Zealand are pooled in order to derive relationships between MCI and stream physico-chemical variables may produce only confusion. For example, instream BOD seems to be of little relevance to macroinvertebrate communities in stony Taranaki streams, but of considerable importance in the North Canterbury streams sampled by Winterbourn *et al.* (1971). Pooling such data would obscure any possible relationship.

The effect of microhabitats on MCI (e.g., run, riffle, pool, debris jam, weed bed) in the same river reach (i.e., experiencing similar water quality) requires assessment.

The application of the MCI to slow-flowing, sandy, silty or muddy streams and rivers also should be investigated. At present, it appears that the technique may be capable of detecting gross enrichment in such conditions but, inevitably, there will be a loss of sensitivity since invertebrate communities extant in unpolluted streams with fine sediments may be very similar to those characteristic of stony streams subject to mild or moderate organic (nutrient) enrichment.

The relationship of MCI values to physical and chemical measurements is an area that warrants considerable attention for two main reasons. First, it will facilitate identification of effluent components that affect invertebrate communities and so will aid in the setting of standards for water right conditions. Second, it should be possible to derive relationships between various physical and chemical variables (perhaps in terms of a water quality index) and MCI values to enable prediction of MCI values for a site.

MCI data may be suitable for use in trend analysis to determine, for example, whether there has been any change in water quality, over time (months, years) as indicated by invertebrate community composition. Such a procedure also should help assess the effectiveness of water management strategies in maintaining or improving water quality.

7 Conclusions

In this report I have outlined a procedure for developing a freshwater Macroinvertebrate Community Index (MCI) that is sensitive to organic pollution. It has uses in water management and shows potential for application throughout New Zealand. The index is simple to apply and takes into account the presence and absence of genera (or higher taxa), but animals do not need counting. This confers considerable savings in time and expense over traditional quantitative biological methods for the assessment of organic enrichment. The index appears relatively independent of sample size and the time of year of sampling—two attributes which simplify its application and interpretation. Further advantages are that the results of MCI analyses can be made available more quickly for feedback into the water management system and they are more readily understood by non-biologists. On the other hand, it is inevitable that there will be some loss of information (cf. quantitative community analyses) and consequently there will continue to be situations where the aims of a study demand the use of quantitative techniques.

However, where quantitiative investigations are not warranted, and where the aims of the study can be achieved using a presence/absence technique, the MCI offers considerable advantages as detailed above.

The MCI is not designed to replace chemical methods of water quality assessment—indeed chemical and biological techniques should be complementary. Further, the existence of a single (index) number that summarises the health of a biological community may facilitate the derivation of relationships with chemical and physical environmental variables. Ultimately, the widespread acceptance and use of biological techniques for water quality assessment and monitoring may depend upon how successfully these relationships can be defined.

Neither is the MCI intended to obviate the need for experience and professional judgement by making biological assessment of river condition a purely numerical process. To quote from Hirsch (1958):

> "The biological method can in some cases be applied by personnel with limited biological background. Stony-bottomed streams sampled during or shortly after the critical period often show the effects of pollution very clearly. In other cases, limitations in the nature of the sampling stations and seasonal changes necessitate more judgment in the collection of samples and the interpretation of results. For this reason, biological investigations of pollution can be most successfully carried out by personnel with an understanding of the natural factors influencing the distribution of aquatic organisms in streams."

Finally, I must stress that a biotic index (such as the MCI) must not become the be all and end all of biological monitoring programmes. A biotic index can be a useful management tool but if progress is to be made, especially in the understanding of habitat requirements and tolerances of macroinvertebrate *species*, then it is essential that detailed quantitative and taxonomic studies continue to be undertaken whenever possible.

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10 Summary of procedure for application of MCI

NB The following procedure assumes that a presence/absence technique is appropriate to the aims of the investigation.

1 Select sampling sites that have similar physical characteristics (e.g., substrate type, flow, water depth, degree of shading). These may be located above and below effluent discharge points, stream confluences etc. Although it is important to eliminate as much non-water-quality-related variability between sampling sites as possible, it is not always possible. Consequently it may be necessary to discuss between-site differences in, for example, substratum type or composition, to help explain differences in MCI values.

2 Samples may be collected using the kick-sample technique, a Surber sampler etc. or via artificial substrates. It is desirable that the technique used be applied consistently between samples/sites.

3 At each site, one sample containing 200–600 animals normally will be adequate although, if possible, triplicate samples should be collected to increase confidence in the MCI value determined and so that within-site variability between samples may be assessed.

Although the MCI does not appear to be unduly dependent upon sample size, additional taxa inevitably will be collected by sample replication. In many cases the resultant taxa list is an important part of resource documentation.

4 Samples should be transferred to pottles and preserved in 70 percent alcohol or 10 percent formalin.

5 In the laboratory each sample should be wet-sieved (e.g., through 2 mm, 1 mm and 0.5 mm mesh sieves) and the various fractions transferred to petri dishes and/or white trays and examined with the naked eye or microscopically as appropriate.

6 Representatives of each taxon should be removed from each sample, identified and stored for future reference in a vial containing 70 percent alcohol.

7 A species x site table of presence/absence (i.e., 1/0 convention) invertebrate distributional data should be constructed.

8 MCI values may be calculated using computer programs (Appendix III) or manually by assigning taxa scores (Table 3) to presence in the species x site table and applying the following equation:

$$MCI = \frac{\text{sum of taxa scores}}{\text{number of scoring taxa}} \times 20$$

9 Any report utilising the MCI should include the species x site data matrix and the table of taxa scores utilised (or reference to a published list of scores). Any additions or amendments to the list of taxa scores should be noted.

Appendix I: Locations of 35 stony riffle sampling sites on 13 streams on the Taranaki ringplain and comments on significant upstream discharges/environmental features.
(Unless otherwise stated all streams flow through dairy/sheep or beef pastureland.)
Site group classifications based upon 3 seasons combined MCI values.

River	Code	Site Group	Grid Reference NZMS1	Altitude (m)	Comment
Kahouri Stream	KA	I	N119 807612	380	Dairy shed washings
	KB	II	N119 845609	322	
	KC	II	N119 863603	293	} abattoir anaerobic pond tannery effluent
	KD	III	N119 898586	277	
Manganui River	MgA*	I	N119 803644	380	Quarry (8 km upstream)
Maketawa Stream	MkA*	I	N109 757705	365	
	MkB*	I	N109 799755	235	
Waiongana Stream	WaA*	I	N109 719735	370	
	WaB*	I	N109 754784	230	Some runoff from dairy waste spray irrigation
	WaC	II	N109 785845	140	Dairy factory cooling water
	WaD	III	N109 774915	60	Piggery, Waitara water supply abstraction
Mangaoraka Stream	MrA*	I	N109 716736	370	
	MrB	II	N109 727891	85	
Waiwakaiho Stream	WkA*	I	N109 704707	350	
	WkB	II	N109 713803	220	
Timaru Stream	TA*	I	N108 562733	410	} Good riparian bush cover along much of stream length.
	TB*	I	N108 508797	68	
Stony River	SA	I	N118 532680	320	} Very turbulent and very little organic enrichment relatively inorganic sediments
	SB	I	N118 501698	220	
	SC	I	N108 455751	75	
Kapoaiaia Stream	KaA*	I	N118 496648	242	
	KaBi	III	N118 404642	70	Dairy factory spray irrigation and organic enrichment of undefined origin
	KaBii	III	N118 400642	67	Dairy factory wastes
Punehu Stream	PA*	I	N118 588475	197	
	PB*	II	N118 527411	75	
Kaupokonui Stream	KpA	I	N119 718512	375	
	KpB*	I	N119 724454	238	Kaponga oxidation pond
	KpC	III	N129 668332	58	Lactose factory cooling water
Inaha Stream	IA	I	N119 754520	375	
	IB	II	N119 787447	210	
	IC	III	N129 763342	80	By-products abattoir
Waingongoro Stream	WgA*	I	N119 779552	365	
	WgB*	I	N119 855479	210	} Eltham oxidation pond, smallgoods factory
	WgC	II	N119 857457	180	
	WgD	II	N129 822363	85	

*Site included in MCI vs site altitude regression equation.

Appendix II: Invertebrate distributional data for single foot-kick samples collected in winter, summer (counts per sample) and spring (presence/absence) from 35 sites on 13 streams on the Taranaki ringplain. X denotes present.

See Taranaki Catchment Commission (1984a) for more specific identifications of taxa for winter and summer sampling.

	KAHOURI												MANGANUI			MAKETAWA					
	A			B			C			D			A			A			B		
	22.7.81	20.10.81	29.1.82	22.7.81	20.10.81	29.1.82	22.7.81	20.10.81	29.1.82	22.7.81	20.10.81	29.1.82	23.7.81	20.10.81	2.2.82	23.7.81	22.10.81	2.2.82	23.7.81	22.10.81	2.2.82
EPHEMEROPTERA																					
Ameletopsis																					
Nesameletus	2	X	13	8	X	2		X	24				16	X	13	64	X	27	47	X	10
Coloburiscus	54	X	37	14		2	3	X	40				14	X		12	X	1	131	X	11
Zephlebia	1		14						1												
Deleatidium	36		184	12	X	22	1	X	28	4		16	58	X	22	188	X	178	114	X	30
Atalophlebioides			3																		
Mauiulus	54		7	15		1			1												
Austroclima	4	X	20	1		4			4						1				7	X	5
PLECOPTERA																					
Stenoperla															1	1	X	1			
Megaleptoperla														X	1	5	X				
Zelandoperla						1			1			1			2				4		1
Zelandobius									1						2	1		2	9		
Acroperla																					
HEMIPTERA																					
Microvelia																					
MEGALOPTERA																					
Archichauliodes	4	X	16			2		X	7			3	1		6	1		3	3	X	8
COLEOPTERA																					
Hydraenidae	1	X	35			1			1			4				1	X	2	3		8
Hydrophilidae	1																				
Staphylinidae																					
Elmidae	7	X	167	4	X	16			18			3	1	X	55	8	X	27	11	X	)
Ptilodactylidae			4																		
Dytiscidae																					
DIPTERA																					
Limonia																					
Aphrophila	13	X	7	2		4	1	X	2		X			X	5	5	X	1	30	X	
Eriopterini		X					1		1	1			1	X		1	X				
Psychodidae								X													
Tanyderidae			1						1			2									
Tanypodinae		X	2			22	3	X	4			2								X	
Podonominae													1								
Maoridiamesa						1	1	X	1		X	22		X		2					
Orthocladiinae		X	43	3		108	42	X	264	143	X	133			6	1	X	1	5		2
Polypedilum							2	X	2	14											
Chironomus									4		X										
Tanytarsini											X	7									
Ceratopogonidae			1			1			2			3									
Austrosimulium			4			6						94									
Stratiomyidae									1												
Empididae	1								3			5							1		1
Anthomyiidae																					
Tabanidae																					

Appendix II—*continued*

						KAHOURI								MANGANUI				MAKETAWA			
		A			B			C			D			A			A			B	
	22.7.81	20.10.81	29.1.82	22.7.81	20.10.81	29.1.82	22.7.81	20.10.81	29.1.82	22.7.81	20.10.81	20.10.82	23.7.81	20.10.81	2.2.82	23.7.81	22.10.81	2.2.82	23.7.81	22.10.81	2.2.82
TRICHOPTERA																					
Orthopsyche																					
Aoteapsyche	5	X	50	4		4			44			4		X	16	11	X	3	17	X	9
Polyplectropus												1									
Hydrobiosis	5		7	2	X	5					X		1		1	5	X		4	X	2
Psilochorema		X	5		X	2							1			3	X				
Neurochorema														X	1		X		2	X	
Hydrochorema																					
Costachorema			1			1									2						
Tiphobiosis												1							6		
Oxyethira									1			4						6			1
Paroxyethira																					
Pycnocentria																					
Beraeoptera	39	X	13	87	X	6	4						13	X	18	90	X	30	248	X	121
Pycnocentrodes	2	X		10	X	1						2	3	X	31	8	X	6	132	X	76
Confluens																					
Conuxia																					
Olinga	15	X	35	1	X	5			8				7	X	3	10	X	4	3		2
Oeconescidae																					
Helicopsyche		X											15	X		81	X	5	16	X	
Triplectides																					
CRUSTACEA																					
Amphipoda																					
OLIGOCHAETA	13		4		X	1	7	X	65	452	X	6	2		1						
HIRUDINEA																					
PLATYHELMINTHES																					
MOLLUSCA																					
Latia																					
Potamopyrgus			2																		
Physa										1											
ACARINA																			1		
NEMATODA					X			X													
Site Score	113	113	153	84	62	139	53	56	142	26	20	91	102	100	125	139	130	107	139	96	104
S	18	16	25	13	10	23	10	12	26	6	7	19	14	14	19	20	18	16	21	14	16
MCI	126	141	122	129	124	121	106	93	109	86	57	95	146	143	132	139	144	134	132	137	130

Appendix II—*continued*

	TIMARU						STONY									KAPOAIAIA								
	A			B			A			B			C			A			Bi			Bii		
	28.7.81	15.10.81	5.2.82	28.7.81	15.10.81	5.2.82	28.7.81	21.10.81	5.2.82	28.7.81	21.10.81	5.2.82	28.7.81	21.10.81	5.2.82	29.7.81	21.10.81	8.2.82	29.7.81	21.10.81	8.2.82	29.7.81	21.10.81	8.2.82
EPHEMEROPTERA																								
Ameletopsis																								
Nesameletus	10	X	19			5	3	X	2	1		13				1	X	11						
Coloburiscus	1	X	1	9	X	38		X			X				1	25	X			X				
Zephlebia			2													1								
Deleatidium	85	X	40		X	35	60	X	228	243	X	103	172	X	383	45	X	3	3	X		9	X	
Atalophlebioides																								
Mauiulus	1					8																		
Austroclima	4		2	1	X	21										4	X	1						
PLECOPTERA																								
Stenoperla		X															X							
Megaleptoperla			5						4		X													
Zelandoperla	17	X	2		X	9	1	X	9	28	X	1		X	1	7	X							
Zelandobius	3	X	7	9	X			X								11			2	X	5	2	X	
Acroperla																								
HEMIPTERA																								
Microvelia																								
MEGALOPTERA																								
Archichauliodes			3	2	X	4			1			1			2			3			2	3		12
COLEOPTERA																								
Hydraenidae		X	1		X			X			X						X							
Hydrophilidae																								
Staphylinidae	1																	1						
Elmidae	2	X	5		X	8	2	X	80	3	X	47	7	X	43		X	11	3	X	11	5	X	84
Ptilodactylidae																								
Dytiscidae																								
DIPTERA																								
Limonia																								
Aphrophila	3	X	1	4	X	8		X	7		X				5	4		1	14	X	4	35	X	2
Eriopterini							9	X	4	4	X	2	2	X	2									
Psychodidae																								
Tanyderidae																								
Tanypodinae																								1
Podonominae																								
Maoridiamesa		X	2	31	X			X							6	1		3	4	X	11	43	X	
Orthocladiinae	7	X	24	18	X	118		X	4		X				1	9		18	20	X	66	104	X	100
Polypedilum																								
Chironomus																								1
Tanytarsini			1	1	X	43												5	1		12	70	X	23
Ceratopogonidae																							X	5
Austrosimulium						4																		
Stratiomyidae																								
Empididae				2		1															2	3		5
Anthomyiidae										1											1	1		
Tabanidae																								

Appendix II—*continued*

	TIMARU						STONY									KAPOAIAIA								
	A			B			A			B			C			A			Bi			Bii		
	28.7.81	15.10.81	5.2.82	28.7.81	15.10.81	5.2.82	28.7.81	21.10.81	5.2.82	28.7.81	21.10.81	5.2.82	28.7.81	21.10.81	5.2.82	29.7.81	21. 10.81	8.2.82	29.7.81	21.10.81	8.2.82	29.7.81	21.10.81	8.2.82
TRICHOPTERA																								
Orthopsyche						2																		
Aoteapsyche				8	X	23			24		X		1	X	40	8	X	3	4		4	13		
Polyplectropus									4			1			1									
Hydrobiosis	1	X	2		X	4	1		1		X	1		X	5	4			1	X		6	X	6
Psilochorema							1	X	1			2	1		3									
Neurochorema				2		6										1								
Hydrochorema																								
Costachorema			1			2		X	3	2		1		X	5	4			1					
Tiphobiosis								X														1		
Oxyethira																1			16			55		
Paroxyethira																			1					
Pycnocentria				13	X			X								2		1						
Beraeoptera	2	X	3	6	X	19		X								12	X	5	3			25		
Pycnocentrodes			1	10	X	8		X			X				2	63	X	632	15	X	6	194	X	7
Confluens																								
Conuxia					X	1																		
Olinga							1									5	X	2						
Oeconescidae																								
Helicopsyche		X															X							
Triplectides																								
CRUSTACEA																								
Amphipoda																								
OLIGOCHAETA								X						X						X	2		X	53
HIRUDINEA																								
PLATYHELMINTHES																								
MOLLUSCA																								
Latia																								1
Potamopyrgus					X															X	3		X	7
Physa																								
ACARINA																							X	
NEMATODA																								
Site Score	86	98	125	76	116	131	64	116	97	60	80	77	35	50	96	120	105	90	65	57	51	75	59	53
S	13	14	19	14	19	21	8	18	14	8	12	10	5	8	15	19	13	15	14	12	13	16	14	14
MCI	132	140	132	109	122	125	160	129	139	150	133	154	140	125	128	126	162	120	92	95	78	93	84	75

Appendix II—*continued*

	WAIONGANA												MANGAORAKA						WAIWAKAIHO					
	A			B			C			D			A			B			A			B		
	27.7.81	22.10.81	4.2.82	27.7.81	22.10.81	4.2.82	22.7.81	18.10.81	4.2.82	27.7.81	19.10.81	4.2.82	27.7.81	22.10.81	4.2.82	27.7.81	29.10.81	4.2.82	24.7.81	15.10.81	1.2.82	24.7.81	15.10.81	1.2.82
EPHEMEROPTERA																								
Ameletopsis													2											
Nesameletus	5	X	1	7	X	22			1				5	X	53	2	X	4	6	X	9	12	X	7
Coloburiscus	44	X	14	132	X	17		X					23	X	15			2	1	X	10	14	X	4
Zephlebia						1							6		1		X	1						
Deleatidium	323	X	155	139	X	73	2	X	2				92	X	156	1	X	71	6	X	100	16	X	19
Atalophlebioides																								
Mauiulus	2			10	X	2							5	X	4		X	15			1			1
Austroclima	5	X	6	15	X	71		X					1		23	2		1			1			1
PLECOPTERA																								
Stenoperla	3	X	1																					
Megaleptoperla																				X		1		
Zelandoperla	6	X	1	1	X										1			1	3	X	3			
Zelandobius	2			3					1		X		1		1	4	X					2		
Acroperla																								
HEMIPTERA																								
Microvelia																								
MEGALOPTERA																								
Archichauliodes	1	X	18	11	X	1		X	6				2	X	2	2	X	26			1		X	
COLEOPTERA																								
Hydraenidae	7	X	35	7	X	7							3	X	36			4		X	1			
Hydrophilidae																								
Staphylinidae																								
Elmidae	8	X	25	8	X	3	1	X	23	2				X	11	5		202	4	X	16		X	3
Ptilodactylidae							1																	
Dytiscidae																								
DIPTERA																								
Limonia																								
Aphrophila	3	X	3	5	X	3	1	X	10	2				X		1	X	26			8	1	X	7
Eriopterini	2	X	1										4											
Psychodidae											X	1												
Tanyderidae																								
Tanypodinae				2					1															
Podonominae																								
Maoridiamesa		X		1				X	7	8	X	3				18	X	5		X	1			47
Orthocladiinae	1	X	1	6	X		51	X	257	153	X	383	8	X		21	X	23	10	X		3		53
Polypedilum											X													
Chironomus																								
Tanytarsini				1				X	61	35	X	40				2	X	14						8
Ceratopogonidae									3			2					X							
Austrosimulium						2			1			6				4		1						
Stratiomyidae				1																				
Empididae							2	X	5	2	X	1	1	X			X	2						
Anthomyiidae									7			6						3						2
Tabanidae																								

Appendix II—*continued*

	WAIONGANA												MANGAORAKA						WAIWAKAIHO					
	A			B			C			D			A			B			A			B		
	27.7.81	22.10.81	4.2.82	27.7.81	22.10.81	4.2.82	22.7.81	18.10.81	4.2.82	27.7.81	19.10.81	4.2.82	27.7.81	22.10.81	4.2.82	27.7.81	29.10.81	4.2.82	24.7.81	15.10.81	1.2.82	24.7.81	15.10.81	1.2.82
TRICHOPTERA																								
<u>Orthopsyche</u>	1						1						1	X	3									
<u>Aoteapsyche</u>	5	X	2	24	X	30							2	X	11	25	X	103		X	31		X	16
<u>Polyplectropus</u>															1									
<u>Hydrobiosis</u>	5	X	5	3		1			2				4		2	2	X	26	1		1		X	5
<u>Psilochorema</u>																								
<u>Neurochorema</u>						1										1		4						4
<u>Hydrochorema</u>																								
<u>Costachorema</u>	1			1	X											1				X	1		X	4
<u>Tiphobiosis</u>				1															1		2	4		
<u>Oxyethira</u>									93	1	X	349						2			1			43
<u>Paroxyethira</u>												2												
<u>Pycnocentria</u>	8												2			33	X	9						
<u>Beraeoptera</u>	297	X	59	37	X	41							16	X	2	7		3	3	X	18	6	X	10
<u>Pycnocentrodes</u>	5	X	5	40	X	2		X	16					X		26	X	385			8	10	X	16
<u>Confluens</u>																1		21						
<u>Conuxia</u>																								
<u>Olinga</u>	91	X	77	26	X	1	1	X					2	X	2					X	1			
Oeconescidae																								
<u>Helicopsyche</u>	176	X	3	225	X		3						1							X			X	
<u>Triplectides</u>																								
CRUSTACEA																								
Amphipoda																								
OLIGOCHAETA	1							X	3	16	X	14	2	X			X							
HIRUDINEA																								
PLATYHELMINTHES																								
MOLLUSCA																								
<u>Latia</u>																								
<u>Potamopyrgus</u>		X					2	X	2								X	6						
Physa																								
ACARINA												1						2						
NEMATODA																								
Site Score	167	140	136	150	121	113	71	67	82	32	23	31	144	98	126	107	86	151	63	102	125	66	83	99
S	24	20	19	23	17	17	11	13	19	9	9	12	21	16	17	19	18	27	9	14	19	10	12	18
MCI	139	140	143	130	142	133	129	103	36	71	51	51	137	123	148	113	95	112	140	146	132	132	138	110

Appendix II—*continued*

	PUNEHU						KAUPOKONUI									INAHA								
	A			B			A			B			C			A			B			C		
	29.7.81	21.10.81	8.2.82	29.7.81	21.10.81	8.2.82	3.8.81	22.10.81	8.2.82	3.8.81	22.10.81	8.2.82	3.8.81	22.10.81	8.2.82	6.8.81	16.10.81	10.2.82	6.8.81	16.10.81	10.2.82	6.8.81	16.10.81	10.2. 82
EPHEMEROPTERA																								
Ameletopsis																								
Nesameletus	4	X	27	1	X	1	5	X	40	40	X	20					X	2			2			
Coloburiscus	35	X	9			1	3	X	70	3	X	44			6	48	X	2	1		4			
Zephlebia						1											X	16		X	44			
Deleatidium	76	X	104			85	99	X	119	28	X	57	3	X	1	106	X	252	38	X	126		X	1
Atalophlebioides																								
Mauiulus			1	1								3				2	X	22	51	X	404			
Austroclima	4	X	12				1		10			2				19		15	8	X	5			
PLECOPTERA																								
Stenoperla							1	X									X							
Megaleptoperla	1	X							4									3						
Zelandoperla			2				3	X	1							1								
Zelandobius	4			5	X	1				1			10	X			X		33	X	1			
Acroperla																1								
HEMIPTERA																								
Microvelia																					1			
MEGALOPTERA																								
Archichauliodes		X	10	1		2	1	X	6		X	28	3	X	22						9			
COLEOPTERA																								
Hydraenidae									12		X	5						2			1			
Hydrophilidae																					1			
Staphylinidae																								
Elmidae	15	X	22	14	X	188	9	X	16	1	X	143	4	X	31	56	X	24		X	10			
Ptilodactylidae											X					32	X	1			11		X	
Dytiscidae																								
DIPTERA																								
Limonia																								
Aphrophila	5	X		2	X		4	X	3	3	X	5	1	X	2	17	X	3						
Eriopterini				1			3	X								9	X	1		X				
Psychodidae																								
Tanyderidae																								
Tanypodinae																								
Podonominae																								
Maoridiamesa			25		X	7			1	2	X	87	74	X	115		X		2				X	
Orthocladiinae			38	95	X	140				20	X	49	25	X	306	3	X	23	1			13	X	1384
Polypedilum																	X				3			
Chironomus																						190	X	53
Tanytarsini			12	1	X	126					X	4		X	26	1								
Ceratopogonidae																								
Austrosimulium													1		1			16	8		4	32		
Stratiomyidae																								
Empididae			1								X				1									4
Anthomyiidae															1									
Tabanidae											X													

Appendix II—*continued*

	PUNEHU						KAUPOKONUI									INAHA								
	A			B			A			B			C			A			B			C		
	29.7.81	21.10.81	8.2.82	29.7.81	21.10.81	8.2.82	3.8.81	22.10.81	8.2.82	3.8.81	22.10.81	8.2.82	3.8.81	22.10.81	8.2.82	6.8.81	16.10.81	10.2.82	6.8.81	16.10.81	10.2.82	6.8.81	16.10.81	10.2.82
TRICHOPTERA																								
Orthopsyche																40	X	1	5					
Aoteapsyche	5	X	43	2	X	27	2	X	21		X	174	45	X	307	4	X	4			8			
Polyplectropus																								
Hydrobiosis	1	X	9			34	3		3	4	X	16	2	X	16	1			2	X	5			23
Psilochorema							2			1														
Neurochorema											X	11				1					1			
Hydrochorema																2								
Costachorema				2							X	6		X	1									
Tiphobiosis																								
Oxyethira												6			7				1					
Paroxyethira																							X	
Pycnocentria	9		5														X	1	17	X	30			1
Beraeoptera	62	X	6			2	54	X	215	10	X	45	8		1									
Pycnocentrodes	97	X	50	39	X	125	8	X	36	50	X	71	25	X	133									
Confluens																								
Conuxia																								
Olinga	10	X	8			4	6	X	25		X	5				1								
Oeconesidae																		1			1			
Helicopsyche	37	X		4	X		4	X	35	1	X													
Triplectides																			4					
CRUSTACEA																								
Amphipoda													1						22	X	23			1
OLIGOCHAETA													1	X	27	1	X	2	3	X	18	296	X	1074
HIRUDINEA																						1		3
PLATYHELMINTHES				2																				1
MOLLUSCA																								
Latia																								
Potamopyrgus	1	X	1	2		3							1	X	1		X	3	40	X	23			
Physa													2					1				1	X	
ACARINA									1															
NEMATODA																								
Site Score	112	107	116	92	52	99	131	109	129	83	128	120	74	65	88	113	114	140	82	71	141	13	28	38
S	16	15	19	16	10	17	17	14	18	13	21	20	16	14	19	17	19	22	16	12	24	6	8	10
MCI	140	143	122	115	104	116	154	156	143	128	122	120	92	92	92	133	120	127	103	118	118	43	70	76

Appendix II—*continued*

WAINGONGORO

	A			B			C			D		
	7.8.81	16.10.81	10.2.82	7.8.81	16.10.81	10.2.82	7.8.81	16.10.81	10.2.82	7.8.81	16.10.81	10.2.82
EPHEMEROPTERA												
Ameletopsis												
Nesameletus	14	X	46	52	X	2	7		3			2
Coloburiscus	6	X	85	5	X	157	3	X	29			26
Zephlebia			1				11	X	9			
Deleatidium	161	X	153	52	X	188	7	X	27	7	X	206
Atalophlebioides												
Mauiulus						15	3	X	51	31	X	107
Austroclima	4		60			45		X	2		X	
PLECOPTERA												
Stenoperla			3									
Megaleptoperla			1									
Zelandoperla			4									
Zelandobius	2			77	X	3	15	X		26	X	2
Acroperla												
HEMIPTERA												
Microvelia												
MEGALOPTERA												
Archichauliodes	2	X	78	3	X	16	3	X	4	1		24
COLEOPTERA												
Hydraenidae		X	30			4		X				
Hydrophilidae												
Staphylinidae												
Elmidae	17	X	105	22	X	120	161	X	131	102	X	351
Ptilodactylidae												1
Dytiscidae												
DIPTERA												
Limonia	1											
Aphrophila	8	X	18		X	10	2	X	1	1		
Eriopterini	5		2									
Psychodidae												
Tanyderidae									5			
Tanypodinae			3						6			
Podonominae												
Maoridiamesa					X	22		X	15			
Orthocladiinae	8		3	31	X	174	13	X	122			
Polypedilum								X	6			
Chironomus								X	71			
Tanytarsini					X		1	X	184			
Ceratopogonidae					X		1	X	1			
Austrosimulium						4			41			21
Stratiomyidae							1	X	9			
Empididae		X								3		
Anthomyiidae												
Tabanidae											X	

Appendix II—*continued*

	WAINGONGORO											
	A			B			C			D		
	7.8.81	16.10.81	10.2.82	7.8.81	16.10.81	10.2.82	7.8.81	16.10.81	10.2.82	7.8.81	16.10.81	10.2.82
TRICHOPTERA												
Orthopsyche												
Aoteapsyche	1	X	6		X	232		X	15	49	X	237
Polyplectropus									1			
Hydrobiosis	2	X	6	1		12	1	X	20		X	2
Psilochorema						1						
Neurochorema		X			X	4	1		3			
Hydrochorema												
Costachorema					X							
Tiphobiosis	3			3		2						
Oxyethira												2
Paroxyethira												
Pycnocentria	20		42	14	X		1		10	11	X	29
Beraeoptera	274		461	12	X	61		X	1	1		17
Pycnocentrodes	42		1	8	X	81	92	X	14	497	X	404
Confluens			1		X	1						
Conuxia												2
Olinga	7	X	29	6		4						
Oeconescidae												
Helicopsyche	28	X	11	4								
Triplectides												
CRUSTACEA												
Amphipoda											X	
OLIGOCHAETA				1				X	26	19		
HIRUDINEA												
PLATYHELMINTHES												
MOLLUSCA												
Latia												
Potamopyrgus			6				2			34	X	77
Physa												
ACARINA												
NEMATODA												
Site Score	129	89	70	97	102	135	99	110	139	68	66	103
S	19	13	24	15	18	22	18	22	27	13	12	17
MCI	136	137	142	129	113	123	110	100	103	105	110	121

Appendix III: BASIC computer program for calculation of MCI values.

Listing of MCI.BAS

```
1Ø CLS:CLEAR:'*** MCI.BAS ***
2Ø '**** program by J.D. Stark, this version 9 May 1985 ****
3Ø OPTION BASE 1
4Ø PRINT TAB(15);"MACROINVERTEBRATE COMMUNITY INDEX (MCI)":PRINT TAB(15);"______
________________________________":PRINT
5Ø PRINT :PRINT "Engage shift-lock (i.e. upper case)":PRINT
6Ø PRINT "Are the taxa codes and species x site matrix on file (Y/N)";:INPUT T$
7Ø IF T$<>"Y" THEN IF T$<>"N" THEN 6Ø
8Ø IF T$="Y" THEN 76Ø
9Ø INPUT "Number of taxa";T
1ØØ DIM CODE(T)
11Ø IF T<=Ø THEN 9Ø
12Ø INPUT "Number of samples/sites";S
13Ø DIM X$(T,S),X(T,S)
14Ø IF S<=Ø THEN 12Ø
15Ø PRINT
16Ø PRINT :PRINT "You will be able to change incorrect taxa code and data entrie
s later":PRINT
17Ø PRINT "Enter counts  or  1 or Ø (for present/absent) or  ØØ  to move to next
 taxon"
18Ø PRINT "-----------------------------------------------------------------
------"
19Ø PRINT
2ØØ GOSUB 113Ø
21Ø 'data input
22Ø FOR I=1 TO T
23Ø PRINT "Taxa code";:INPUT CODE(I)
24Ø PRINT A$(CODE(I));
25Ø FOR J=1 TO S
26Ø PRINT TAB(3Ø);"Sample/Site ";J;
27Ø INPUT X$(I,J)
28Ø X(I,J)=VAL(X$(I,J))
29Ø IF X$(I,J)="ØØ" THEN 31Ø
3ØØ NEXT J
31Ø PRINT
32Ø NEXT I
33Ø 'error correction routine
34Ø PRINT :PRINT "Do you want to correct any entry errors in taxa x site data (Y
/N)";:INPUT E$
35Ø IF E$<>"Y" THEN IF E$<>"N" THEN 35Ø
36Ø IF E$="N" THEN 5ØØ
37Ø CLS:PRINT "Here is a list of current taxa and their code numbers"
38Ø FOR I=1 TO T
39Ø PRINT "Taxon ";I,LEFT$(A$(CODE(I)),LEN(A$(CODE(I)))-2);TAB(45);"Code # =";CO
DE(I)
4ØØ NEXT I
41Ø PRINT :PRINT "Enter taxon (= row) number where data error is [N.B. NOT the t
axon code #]";:INPUT I
42Ø PRINT:PRINT "Here are the entries for each site for ";LEFT$(A$(CODE(I)),LEN(
A$(CODE(I)))-2):PRINT
43Ø PRINT "Site # ";:FOR J=1 TO S:PRINT J;"";:NEXT J:PRINT
44Ø PRINT "Entry  ";:FOR J=1 TO S:PRINT X(I,J);"";:NEXT J:PRINT
45Ø PRINT :PRINT "Enter site (= column) number where incorrect entry is";:INPUT
J
46Ø PRINT
47Ø PRINT "Enter corrected value ";:INPUT X(I,J)
48Ø PRINT
49Ø GOTO 34Ø
5ØØ PRINT :PRINT "Do you want to correct any errors in the list of taxa code num
bers (Y/N)";:INPUT C$
```

```
510 IF C$<>"Y" THEN IF C$<>"N" THEN 510
520 IF C$="N" THEN 640
530 CLS:PRINT "Here is a list of current taxa and their code numbers"
540 FOR I=1 TO T
550 PRINT "Taxon ";I,LEFT$(A$(CODE(I)),LEN(A$(CODE(I)))-2);TAB(45);"Code # =";CO
DE(I)
560 NEXT I
570 PRINT :PRINT "Enter number of taxon that you wish to change";:INPUT I
580 PRINT "Enter new code number";:INPUT CODE(I)
590 GOSUB 1140
600 PRINT "New taxon = ";LEFT$(A$(CODE(I)),LEN(A$(CODE(I)))-2)
610 PRINT
620 GOTO 500
630 ' save data on disk
640 PRINT "Save data on disk (Y/N)";:INPUT D$
650 IF D$<>"Y" THEN IF D$<>"N" THEN 650
660 IF D$="N" THEN 910
670 PRINT "File name for taxa x site data";:INPUT F$
680 OPEN "O",#1,F$
690 WRITE#1,T;S:'taxa , sites
700 FOR I=1 TO T:FOR J=1 TO S
710 WRITE #1,X(I,J)
720 NEXT J:NEXT I:CLOSE 1
730 PRINT "File name for taxa codes";:INPUT F1$

740 OPEN "O",#1,F1$:WRITE#1,T:FOR I=1 TO T:WRITE #1,CODE(I):NEXT I:CLOSE 1
750 GOTO 910
760 GOSUB 1130
770 'get taxa codes from disk file
780 PRINT :PRINT "File name of taxa code file";:INPUT F1$
790 OPEN "I",#1,F1$
800 INPUT #1,T
810 DIM CODE(T)
820 FOR I=1 TO T
830 INPUT #1,CODE(I)
840 NEXT I
850 CLOSE 1
860 'get taxa x site data from disk
870 PRINT "File name of taxa x site data";:INPUT F$:OPEN "I",#1,F$:INPUT #1,T,S
880 DIM X(T,S):FOR I=1 TO T:FOR J=1 TO S:INPUT #1,X(I,J):NEXT J:NEXT I:CLOSE 1
890 GOTO 340
900 ' calculate MCI
910 V=0
920 FOR I=1 TO T
930 V=VAL(RIGHT$(A$(CODE(I)),2))
940 FOR J=1 TO S
950 IF SGN(X(I,J))=1 THEN 970
960 GOTO 980
970 X(I,J)=V
980 NEXT J
990 NEXT I
1000 FOR J=1 TO S
1010 FOR I=1 TO T
1020 C(J)=C(J)+X(I,J)
1030 C1(J)=C1(J)+SGN(X(I,J))
1040 NEXT I
1050 NEXT J
1060 'print MCI results (pres/abs)
1070 CLS
1080 PRINT "SITE #","SITE SCORE","TAXA","MCI"
1090 FOR J=1 TO S
1100 PRINT J,C(J),C1(J),(C(J)/C1(J)*20)
1110 NEXT J
1120 END
1130 DIM A$(200):'string of taxa names and codes
```

```
114Ø A$(1)="Ichthybotus  8"
115Ø A$(2)="Coloburiscus  9"
116Ø A$(3)="Siphlaenigma  9"
117Ø A$(4)="Nesameletus  9"
118Ø A$(6)="Ameletopsis  1Ø"
119Ø A$(7)="Oniscigaster  1Ø"
12ØØ A$(8)="Deleatidium  8"
121Ø A$(1Ø)="Austroclima  9"
122Ø A$(11)="Mauiulus  5"
123Ø A$(12)="Atalophlebioides  9"
124Ø A$(13)="Zephlebia group  7"
125Ø A$(14)="Arachnocolus  8"
126Ø A$(15)="Stenoperla  1Ø"
127Ø A$(16)="Austroperla  9"
128Ø A$(17)="Megaleptoperla  9"
129Ø A$(18)="Zelandoperla  1Ø"
13ØØ A$(19)="Zelandobius  5"
131Ø A$(2Ø)="Acroperla  5"
132Ø A$(22)="Spaniocercoides  8"
133Ø A$(24)="Cristaperla  8"
134Ø A$(26)="Spaniocerca  8"
135Ø A$(28)="Xanthocnemis  6"
136Ø A$(4Ø)="Sigara  5"
137Ø A$(44)="Microvelia  5"
138Ø A$(49)="Dytsicidae  5"
139Ø A$(58)="Staphylinidae  5"
14ØØ A$(59)="Elmidae  6"
141Ø A$(63)="Hydrophilidae  5"
142Ø A$(64)="Hydraenidae  8"
143Ø A$(67)="Ptilodactylidae  8"
144Ø A$(68)="Zelandotipula  6"
145Ø A$(69)="Limonia  6"
146Ø A$(7Ø)="Aphrophila  5"
147Ø A$(71)="Eriopterini  9"
148Ø A$(72)="Paralimnophila  6"
149Ø A$(73)="Hexatomini  5"
15ØØ A$(82)="Culex  3"
151Ø A$(84)="Paradixa  4"
152Ø A$(85)="Austrosimulium  3"
153Ø A$(87)="Tanypodinae  5"
154Ø A$(88)="Podonominae  8"
155Ø A$(89)="Maoridiamesa  3"
156Ø A$(9Ø)="Lobodiamesa  5"
157Ø A$(91)="Orthocladiinae  2"
158Ø A$(92)="Tanytarsini  3"
159Ø A$(99)="Harrisius  6"
16ØØ A$(1ØØ)="Polypedilum  3"
161Ø A$(1Ø1)="Chironomus  1"
162Ø A$(1Ø6)="Mischoderus  4"
163Ø A$(1Ø7)="Psychodidae  1"
164Ø A$(1Ø8)="Ceratopogonidae  3"
165Ø A$(1Ø9)="Stratiomyidae  5"
166Ø A$(11Ø)="Tabanidae  3"
167Ø A$(111)="Empididae  3"
168Ø A$(114)="Syrphidae  1"
169Ø A$(115)="Muscidae  3"
17ØØ A$(116)="Ephydridae  4"
171Ø A$(119)="Orthopsyche  9"
172Ø A$(12Ø)="Aoteapsyche  4"
173Ø A$(122)="Oxyethira  2"
174Ø A$(123)="Paroxyethira  2"
175Ø A$(126)="Psilochorema  8"
176Ø A$(127)="Tiphobiosis  6"
177Ø A$(128)="Costachorema  7"
178Ø A$(13Ø)="Hydrobiosis  5"
```

```
1790 A$(131)="Neurochorema  6"
1800 A$(132)="Hydrochorema  9"
1810 A$(135)="Polyplectropus  8"
1820 A$(137)="Hydrobiosella  9"
1830 A$(139)="Helicopsyche  10"
1840 A$(141)="Oeconesidae  9"
1850 A$(146)="Hudsonema  6"
1860 A$(148)="Triplectides  5"
1870 A$(154)="Pycnocentrodes  5"
1880 A$(155)="Beraeoptera  8"
1890 A$(156)="Confluens  5"
1900 A$(157)="Conuxia  8"
1910 A$(158)="Olinga  9"
1920 A$(159)="Pycnocentria  7"
1930 A$(161)="Nymphula  4"
1940 A$(162)="Microchorista  7"
1950 A$(163)="Archichauliodes  7"
1960 A$(164)="Platyhelminthes  3"
1970 A$(165)="Hirudinea  3"
1980 A$(166)="Nematoda  3"
1990 A$(167)="Ostracoda  3"
2000 A$(168)="Amphipoda  5"
2010 A$(169)="Paratya  5"
2020 A$(170)="Paranephrops  5"
2030 A$(171)="Tanaidacea  4"
2040 A$(172)="Latia  3"
2050 A$(173)="Ferrissia  3"
2060 A$(174)="Potamopyrgus  4"
2070 A$(175)="Physa  3"
2080 A$(176)="Physastra  5"
2090 A$(177)="Gyraulus  3"
2100 A$(178)="Sphaeridae  3"
2110 A$(180)="Melanopsis  3"
2120 A$(181)="Acarina  5"
2130 A$(183)="Oligochaeta  1"
2140 A$(184)="Collembola  6"
2150 A$(186)="Isopoda  5"
2160 RETURN
```

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7. A guideline to skifield development. ($2) 1980
8. A wetlands guideline. ($5) 1982
9. A water and soil guideline for mining. ($10) 1983
10. A water and soil guideline for pipeline easements. ($3) 1985