A BIOLOGICAL MONITORING SYSTEM FOR THE FRESHWATER RESOURCES OF MADEIRA; SOME PRELIMINARY RESULTS

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With 12 figures and 3 tables

ABSTRACT. This paper summarises one year's collections from three (of a total of six) rivers, in order to establish a Regional monitoring method for biological assessment of water quality, impact assessment, land-use and river habitat surveys. A water quality gradient from clean to polluted across the three rivers is expressed through selected physico-chemical parameters and freshwater macroinvertebrates communities using the BMWP score. The BMWP methodology is concluded as unsuitable for Madeira due to the the fact that it operates at family level. Also the low diversity and highly seasonal nature of the Region's freshwater fauna emphasises the need for a method specific to Madeira.

INTRODUCTION

Numerous freshwater biological monitoring systems exist in many regions for assessing a water courses biological quality, in conjunction with physico-chemical parameters. The majority of monitoring methods are based upon benthic macro invertebrates and their response to stress, generally organic pollution. WARREN (1971) described the basis of biological monitoring (summarized) as "A location with not too extreme physical/chemical characteristics will allow plant and animal species to colonize resulting in an assemblage of species and the formation of complex relationships with time. A biological community with definite characteristics is established, dependent upon the local resources and conditions. **Thus, the biological community will change if these conditions change due to either pollution events or natural events**. Since the environment at a location largely determines what organisms are able to inhabit it, **the inhabitants constitute BIOLOGICAL INDICES of environmental change.**", WARREN 1971.

Most biological monitoring methods are either (i) Pollution Indices, (ii) Diversity Indices or (iii) Comparative Indices. Although methods differ and each has limitations they

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Bol. Mus. Mun. Funchal, Sup. no. 4: 325-351, 1995 ISSN 0870-3876

are based upon the comparison of detectable changes in communities in certain conditions. A non-stressed "clean water" is diverse with no predominance of any particular species. The organisms present are adapted to the local physico chemical characteristics, some are highly pollution intolerant "clean water" species. e.g. Plecoptera. A stressed polluted water community exhibits a disturbed ratio between the abundance of certain organisms and a decrease in diversity. As non-tolerant species disappear, the prevailing conditions will be exploited by a few pollution tolerant species, leading to a disproportionate increase in their abundance.

Existing methods generally assess aquatic organic pollution and are well documented, becoming more sophisticated and quantitative in order to effectively express biological data to non biologists (Persoone and de PAUW 1978; HYNES 1960, MASON 1989, HELLAWELL 1989). Table 1 summarizes some methods, presented chronologically dating from the beginning of the century. The original Saprobien system was entirely qualitative, based upon the direct observation of collected microorganisms, requiring a high level of specialist knowledge. Not surprisingly, it was considered labour intensive, time consuming and unquantifiable. Subsequent Saprobien methods are more quantitative.

The more widely used methods are semi-quantitative, employing benthic macro invertebrates and a standardized sampling procedure (specified time or area). Data is presented as a score or index based upon the presence/absence/abundance of indicator species. Pollution intolerant taxa are high scorers, pollution tolerant taxa are low scorers. The most recent systems, such as RIVPACS use predictive techniques (see FURSE et al 1987). Such methods are specifically devised for freshwater biological monitoring. Diversity and comparative indices can be applied to a number of ecological studies. Many monitoring systems use benthic macro invertebrate communities for reasons summarized by various authors (FURSE 1987, HELLANTHAL 1982 and HELLAWELL 1989):

The wide diversity and abundance in most freshwater habitats.

A relatively sedentary habit relates the presence of taxa to environmental conditions at point of collection.

The life cycle length of many species gives an overview of local conditions at a site over several months.

Dispersal and colonization signify that few sites are outside some species geographical range).

Complex community interrelationships results in a simultaneous response to environmental stress.

Many species are bioaccumulators of toxic substances.

Qualitative / semi quantitative sampling is relatively easy and inexpensive.

A Monitoring Method for Madeira

During 1990-91, it came to the attention of the author that no monitoring method existed for assessing the freshwaters of Madeira. Some of the more urbanized areas have extremely polluted stretches of freshwater. At altitude some water courses receive heavily polluting organic discharge from piggeries, leachates from the disused rubbish dump at Cabeço Gordo. The extremely short profile of the rivers affected by organic pollution threatens coastal and lower lying areas which are of substantial recreational, agricultural, ecological, fishery and touristic value. The predominance of certain endemic taxa lends the Regional freshwaters considerable ecological status.

A proposal to establish a simple based benthic macro invertebrates monitoring method was accepted by the Regional Government in late 1990. Such a method would be adapted specifically to the Region by virtue of it's depauperate freshwater fauna, i.e. the absence of Plecoptera and other clean water indicators, as well as the high levels of endemism in many of the groups present, e.g. 10 endemic species of Trichoptera, 13 species of endemic Coleoptera.

Methods

A baseline study is essential in order to separate temporal events i.e., seasonal patterns and life cycles from organic pollution effects, the principal form of pollution in the Region. There may also exist disparities between rivers on the North and the South due to the central mountain barrier and different climatic regimes. Madeira has over one hundred catchments, from which six of the larger ones were selected (Figure 1); Ribeiro de Machico, Ribeira de Santa Cruz, Ribeira de São João, Ribeira Brava, Ribeira de São Vicente and Ribeiro Frio. Together these rivers include unpolluted, semi polluted and polluted sites on both sides of the island over an altitude gradient. Monthly biological and physico chemical samples were taken at easily accessible sites during 1991.

Benthic macro invertebrates collections were made by kick sampling into a hand net (mesh size 0.95mm) for 5 minutes, whilst moving upstream, crossing the river bed diagonally. If necessary, the sampling period was subdivided in order to cover several microhabitats. Rocks and aquatic plants were sampled by hand. Collected specimens were preserved in 70% alcohol. Water samples were also collected for physico chemical analysis (table 2). Standard habitat sheets were filled out at each site. In the laboratory, samples were sorted, the invertebrates identified to a determined level and enumerated (table 3). Specimens that were difficult to identify were sent off to specialist taxonomists. Chemical analyses of the water samples were carried out at the Regional Public Health Laboratories.

Results

Due to the large amount of data the project has generated, results from three rivers will be covered from two seasons in order to illustrate the presence of a detectable pollution gradient. The rivers represent an unpolluted river, a semi-polluted river and an organically polluted river; Ribeiro Frio, Ribeiro de Machico and Ribeira de São João, respectively. The sparsely populated Ribeiro Frio catchment ($53.39km^2$) is situated on the NE of the island.

There is some agricultural activity in the lower and virtually no human activity in the upper part of the catchment except for the small scale trout farm at Ribeiro Frio, a possible source of introduction of exotic species through stocking activity.

Ribeira de Machico (25.43 km^2) is situated in one of the most mature river valleys on the island with considerable levels of agricultural activity and along the river valley to the coast. Ribeira de São João (15.84 km^2) situated to the west of central Funchal is heavily organically polluted by domestic sewage and effluent discharge and illegal dumping of rubbish along the water course.

Chemical Analyses

Unfortunately, facilities were not available to carry out BOD_5 analyses a reliable indicator of organic pollution. However, it is possible to detect a pollution gradient through other physico-chemical parameters such as conductivity (Figure 2a,b,c) measured in micro siemens (μs) at all sites throughout 1991. Conductivity expresses levels of dissolved substances and ions. Madeira is almost entirely basaltic, thus minerals are not readily yielded and unpolluted waters have low background conductivity levels.

Ribeiro Frio's (fig.2a) two upper sites maintain characteristically low conductivity readings throughout the year (between 40-60μs/cm). They are close to source receiving runoff from a small, isolated upper area of the catchment. The lower sites have higher conductivity levels, situated in areas of low level agricultural activity and habitation. The maximum value of 193μs/cm is obtained at the lowest site in the summer. R. de Machico (fig.2b) exhibits higher conductivity levels at all sites compared to R. Frio derived from agricultural and urban sources. Maximum values (348μs/cm) are reached in the summer months when flow is low, the minimum value is 106μs/cm. The São João river's (fig.2c) lowest reading at site one in January is 239μs/cm exceeds R. Frios maximum value. The highest value (601 symbol 109 \f"Symbol"μs/cm) occurs in the summer, and is approximately three times that of R. Frio. The enhanced values are derived from the various untreated effluents discharging along the three sites. Levels of dissolved substances are generally inversely proportional to flow.

Alkalinity, a measure of hardness is generally expressed in $CaCO_3$ mg/l and indicates the buffering capacity of a water body. Madeira's waters are extremely "soft" with poor buffering capacity, a geological facet. R. Frio's upper sites (fig 3a) have very low alkalinity readings of between 18 and 34 mg/l $CaCO_3$. The lower sites have higher values, with a Summer maximum of 70 mg/l $CaCO_3$. Like conductivity, there is an inverse relationship between alkalinity and flow. R. Machico (fig. 3b) also displays a seasonal trend in alkalinity values with minimum values at the upper sites double the value of R. Frio's minimum reading, emphasizing the effect of light and diffuse sources of pollution upon the Island's poorly buffered waters. The summer maximum of 88mg/l $CaCO_3$ is not much greater than the Summer maximum of R. Frio. Ribeira de Saõ João (fig. 3c) exhibits enhanced alkalinity values from the various discharges although buffering capacity of the water body is still poor. Minimum readings in January when the flow level is greater are between 63 and 66 mg/l $CaCO_3$. Peak values are attained in July again at the upper sites, indicating that these sites are especially receiving some discharge. The maximum values are 151mg/l $CaCO_3$, twice that of R. Frio.

An important factor in aquatic organic pollution is the essential nutrient nitrate. Naturally present in low concentrations, high nitrate levels introduced into the environment from untreated organic discharge, lead to eutrophication, altering the biocoenosis and producing algal blooms. Being highly soluble and mobile, nitrate is readily leached into water courses, and is the most biologically utilisable form of nitrogen. Low levels during the summer are due to reduced runoff, increased rates of evaporation, transpiration and biological uptake. The situation is reversed in the autumn and winter, due to leaf fall, decomposition, and increased run off. In all 3 graphs where nitrate levels are below the detectable range by the method employed (< 0.5 mg / l) an arbitrary value of 0.4 mg / l has been attributed.

R. Frio (fig. 4a) maintained low nitrate levels throughout 1991. The lower two sites show increased levels in January, related to precipitation and runoff plus low level agricultural activity. The anomalous reading at site 1 in September is due to the damming of the site and the buildup of a layer of organic detritus. R. de Machico (fig.4b) also had low nitrate levels throughout the sampling period, related to flow patterns and active uptake by plants. Increased levels in the winter months are linked to increased flow. The higher values in January and November of 2.4 mg/l are considerably greater than those of R. Frio due to greater agricultural activity and domestic discharge combined with precipitation. R. São João (fig 4c) nitrate levels far exceed those of the previous two rivers. With the exception of July, levels of not less than 5.6 mg/l were recorded with two peaks of 12 mg/l indicating the extremely low quality effluents the river receives. The drop in July is related to summer flow and algal growth. The excessive nitrate levels pose a serious threat to water quality made evident by the presence of extensive algal masses along the Funchal bay shoreline at the river mouth. Maximum nitrate levels are fifteen times greater than those for R. Frio.

The chemical analyses for the three rivers reveal a definite pollution gradient. The sites for R. Frio show are almost always of good quality whilst R. Machico reflects diffuse urban / agricultural pollution and São João heavy organic urban pollution. The revealed seasonal trends emphasize the necessity of baseline studies in order to detect such underlying factors.

Biological Results

The BMWP score system (Biological Monitoring Working Party 1978) has been applied to the macro invertebrates collected from the three selected rivers for Spring (March) and Summer (July) 1991. The BMWP system (figure 5) attributes a value from 1 to 10 to selected invertebrate taxa at family level (numbers alongside the rows in the histograms).

Higher BMWP values are attributed to non tolerant taxa and vice versa. The sum of these values is the BMWP score. The Average Score per Taxon (ASPT) is the mean value derived by dividing the score by the number of taxa, regarded as a more reliable figure since it is less influenced by sampling effort (ARMITAGE et al 1983). As previously mentioned, all of the systems in use have limitations; the BMWP system does not consider levels of abundance, and some experts claim that the BMWP increases with sampling effort, leading to unrepresentative scores.

The BMWP scores for Spring 1991 Ribeiro Frio sites 1, 2 and 4 were 32, 11 and 24 respectively (figure 6 a,b,c). ASPT values decrease as one progresses downstream. The presence of *Polycentropus flavostictus* HAGEN 1865 (BMWP value 7) at site 1 raises the score and ASPT (4.57) considerably. Even though diversity is greater at site 4, the taxa have low BMWP values, a problem concerning most of the Madeiran freshwater macro invertebrate fauna, exacerbated also by limited diversity, with only one or very few species per family or genus. e.g *Hydropsyche maderensis* HAGEN 1865 (Macronesian species) and *Polycentropus flavostictus* (endemic species).

Eight taxa were collected at site 1 (fig 6a), 4 have attributed BMWP values of 4 or less, emphasising the lack of high scoring taxa in the Region. Thus the BMWP score (developed for use in the United Kingdom) gives a misleadingly low score at an unpolluted site. Preliminary findings suggest that *Polycentropus flavostictus* is a clean water indicator but stenothermic with a restricted distribution. Simuliidae, an intermediate scorer and filter feeder is widespread occurring at sites with sufficient flow. Due to increased flow at this time of year, Simuliidae is widely distributed. Abundance levels are balanced across the taxa although low, with the exception of Baetis rhodani PICTET 1843-45 a spectacularly successful colonist of the Regions freshwater habitats.

Site 2 (fig.6b) is an anomalous site often experiencing a temperature inversion relative to the upstream site and possessing few micro habitats. The river is diverted upstream, passing through a trout farm; where potential invertebrate colonizers of downstream habitats by invertebrate drift are predated. These factors may explain why only three taxa were found in March resulting in a BMWP of 11 (ASPT 3.66). The family Chironomidae is large by regional standards and may merit further taxonomic discrimination in order to produce a more effective monitoring method. Site 4 (Fig 6c), exhibits greater diversity, with 9 taxa (BMWP 24, ASPT 3). The presence of Planorbidae, Physidae and Hydrobiidae (all score 3) is typical of the Region's lowland sites.

Spring sites 1,3 and 5 for R. Machico (Fig. 7a,b, and c) show the effect of diffuse urban agricultural runoff upon macro invertebrate assemblages. Diversity is mildly enhanced by the presence of relatively pollution tolerant taxa, resulting in higher BMWP scores, 40, 45 and 22 across the sites compared to Ribeiro Frio. However, the ASPT's reveal the macroinvertebrate assemblages to consist of low scoring taxa (ASPT 4, 4.09 and 3.14). At site 1 (fig.7a) there are 13 taxa, with increased numbers of Erpobdellidae Dina lineata (O.F.

Msymbol 154 \f"MS LineDraw" \s 12ller,1774), Simuliidae and Baetis rhodani. The presence of Oligochaeta (Naididae) typical of organically enriched waters as is Asellus aquaticus (BMWP values 1and 3), lowers the score. *A. aquaticus* has been found in the lower reaches of rivers affected by an organic load on the South of the island only, suggesting recent introduction. Simuliidae (BMWP value 5) exploits the water borne particles. Within the family Chironomidae Tanytarsini and Chironomini were easily recognizable in a family where identification is problematic, an advantage should family level identification proves insufficient. There are 3 different Trichoptera taxa: Psychomyiidae (*Tinodes sp.*), Hydroptiliidae and Hydropsychidae (BMWP values 8,6 and 5 respectively)..

The site 2 macro invertebrate assemblage (fig 7b) is very similar to site 1, with 12 low scoring taxa. Molluscs are better represented, all with attributed BMWP values of 3, except *Ancylus fluviatilis* MÜLLER . The presence of *A. aquaticus* confirms the low biological quality of the site. Hydroptilidae and Hydropsychidae have "mid range" BMWP values of 6 and 5 respectively. Aeshnidae (BMWP value 8) raises the site's ASPT. The reduced diversity (8 taxa) and BMWP score of 22 (ASPT 3.14) illustrates the cumulative effect of low water quality upon the biocenoses at site 5 (fig. 7c). The maximum BMWP value of 4 is attained by *Baetis rhodani* which dominates the sample. Planorbidae *(Gyraulus parvus* (MÜLLER)), Hydrobiidae (*Pseudamnicola similis* DRAPARNAUD 1805) and *Asellus aquaticus* have BMWP values of 3. Chironomidae and *Lumbriculus variegatus* MÜLLER 1774, score 2 and 1 respectively. A stressed community is already clearly discernible early in the year.

Ribeira de São João possesses a macro invertebrate community (fig. 8a, b and c) typical of stressed conditions, illustrated at site 1 (fig.8a) by the presence of Chironomidae including *C.thummi* and Oligochaeta (Naididae). Also, *B. rhodani* is present in disproportionate numbers, over 300 individuals from a 5 minute sample. Dryopidae (*Dryops luridus* ERICHSON) has the highest BMWP value of 5. The BMWP site score and ASPT are 18 and 3 respectively. At site 2 diversity is low, 4 pollution tolerant taxa (fig.8b) with a lower BMWP score of 12 but the same ASPT as site 1. The presence of Psychodidae (has no attributed BMWP value) part of the constituent fauna of sewage trickle filters (C.F. MASON 1989), is indicative of its extreme tolerance to organic effluents. At site 3 (fig. 8c) Oligochaeta, Asellidae and Psychodidae again indicate poor conditions. *B. rhodani* is abundant but less so than the two previous sites possibly due to the cumulative effect of polluting discharges. The BMWP score is 13 but the ASPT is considerably lower than the other sites at 2.6 indicating pollution tolerant taxa.

In Summer (July) 1991 the rivers exhibit lower flow rates and thus fewer micro habitats. In the case of polluted rivers, effluents make up a greater proportion of the overall flow, exherting a more profound effect upon the biota. R. Frio site 1 (fig 9a) shows a decrease in diversity and abundance, Chironomidae BMWP value 2 form the major part of the fauna. Hydracarina, are not attributed a BMWP value because of their small size and complicated taxonomy. Simuliidae are now absent, indicating reduced flow compared to the Spring sample.

The endemic Trichoptera *Polycentropus flavostictus* and the Glossosomatid *Synagepetus punctatus* HAGEN 1859 have the highest BMWP values of 7, raising the BMWP score the ASPT. Site 2 (fig. 9b) shows greater diversity but low numbers of individuals compared to the Spring. Oligochaeta (*Lumbriculus variegatus,* BMWP value 1) is present in very low numbers (3 individuals) as are Physidae and Planorbidae (BMWP value 3, number of individuals 1). The same Chironomid taxa as site 1 are present, *B.rhodani* is also present but not predominant. The highest scoring taxa (score 5) is Coleopteran. Although the BMWP score is 18, only slightly lower than site 1, the ASPT is depressed by low scoring taxa.

Diversity at site 4 (fig.9c) is also reduced. Planorbidae, Physidae, Lymnaeidae and Hydrobidae (all score 3) form the greater part of the sample, with Planorbidae (*Gyraulus parvus*) being the most abundant. Oligochaeta (Naididae BMWP value 1) are slightly more abundant than the Planorbidae, indicating a possible light organic load at the site. The most abundant taxon is Hydroptilidae (*Oxyethira spinosella* MCLACHLAN 1884, BMWP value 6). *O. spinosella* appears to predominate on the North of the island and *Hydroptila sp.* on the South. Abundance increases in conjunction with the seasonal growth of aquatic filamentous algae upon Hydroptilids feed. Although the numbers of Planorbidae, Naididae and Oxyethira exceed the other groups, the difference is not exaggerated suggesting that the assemblage is not overly stressed. The BMWP is higher than the other two sites 23, but the ASPT is 3.3 due to the presence of mollusca and oligochaeta.

Summer samples (fig.10a,b and c) from Ribeiro de Machico indicate a more stressed community and a decline in water quality due to decreased flow (fig 10a). There are 9 taxa at site one (BMWP score 30, ASPT 3.3), 8 of which have BMWP values of 3. As in the lower R. Frio site, freshwater mollusca predominate (*Pisidium* sp., Planorbidae, Physidae, Lymaeidae and Hydrobiidae all score 3). Planorbidae (233 individuals) and Physidae (*P. acuta* 402 individuals) increase in abundance, typical of both a stressed community and a seasonal increase. *A. aquaticus* is present in low numbers (score 3), as is *Hydropsyche maderensis* (BMWP value 5). *Baetis. rhodani* is no longer a major constituent of the biota possibly due to a phase of recent emergence. The biota collected at site 3 (fig. 10b) also reflect declining conditions (BMWP score 27, ASPT 3). The same mollusc taxa are present although in different proportions. The bivalve Sphaeridae (*Pisidium casertanum* BMWP value 3) is the most abundant (60 individuals) followed by Planorbidae (43 individuals). *A. aquaticus* again is present in low numbers as are Chironomidae (score 2), Hydroptilidae. (BMWP value 6) and Hydropsychidae (BMWP value 5). Diversity at site 5 (fig. 10c) is very low, only 4 taxa. Planorbidae is most abundant (score 3) followed by Oligochaeta (BMWP value 1). The other two grou present are Physidae and Hydracarina (score 3 and no attributed score).

R. São João in Summer splays all the characteristics of a heavy organic load due to the increased proportio of effluent in the overall flow . Site 1 (fig.11a) contains 9 taxa of which the Planorbidae, L nnaeidae, Physidae (BMWP value score 3), Psychodidae and

Chironomidae (including *Chironomus thummi*) are extremely pollution tolerant. Disproportionate numbers of Planorbidae (>200) and Physidae (>400) occur. *Baetis rhodani is* absent but Cloeon *dipterum* Linnaeus, generally found in still waters, is present. The BMWP score is low ,12, and the ASPT indicates the lack of clean water taxa. Diversity declines further at site 2 (fig.11b) to 5 taxa with an ASPT of 3 derived from a BMWP score of 12. Physidae (*P.acuta*) occurs in higher numbers. The presence of Muscidae (*Limnophora sp.*) larva (no attributed score) highlights the low quality of the site. Site 3 (fig.11c) has a BMWP score of 29 and an ASPT of 3,.2, raised by the presence of *Ancylus fluviatilis* (BMWP value 6). Again, Mollusca predominate, Physidae (*P. acuta*) being the most abundant (325 specimens), followed by Hybrobiidae (212 specimens). Two new Regional records of aquatic mollusca were collected at this site: *Planorbarius (Coretus) corneus* (LINNAEUS) and *Lymnaea (Radix) peregra* (MÜLLER). Both species are common in Continental Europe. (Oligochaeta BMWP value 1) indicates heavy organic pollution. *Limnophora sp.* was also found at this site.

Financial support from the European Regional Development Centre (CEDRE) during 1992, allowed interrgional cooperation in the development of the project. Preliminary statistical analyses were carried out with Mike Furse at the Institute of Freshwater Ecology (IFE) River Lab (UK)in September 1992, confirming the difficulties outlined in the text. CANONICAL COMMUNITY ORDINATION (CANOCO) employs ordination, cluster analyses and non-linear techniques to detect specific trends and effects in the biota. Two months biological, physical and chemical data of all the sites (28 sites) in all the rivers (6 rivers), was analysed in order to derive gradients to identify discrete macro invertebrate assemblages. Species from the most grossly polluted sites were excluded from analyses since they reduced discriminative power for the remaining species. An ordination plot of macro invertebrate species reveals some weak preliminary gradients (fig. 12), 5 arbitrary groups were defined. Groups 1 and 2 contain relatively pollution tolerant taxa. Those in group 1 tend to occur in higher numbers than those in group 2. This is now known not to be the case with *G. parvus* and Physidae, the freshwater snails in group 2 which increase dramatically in number in the Summer, reinforcing the importance of baseline studies in order to detect strong seasonal trends. Group 3 contains a large number of taxa, illustrating the difficulty in distinguishing the range of intermediate sites at this taxonomic level. Group 4 contains *B. rhodani* and Hydracarina, widely distributed taxa. Finally group 5 contains *Polycentropus flavostictus*, consistently found in higher clean water sites.

Discussion

Preliminary analyses give some indication of macro invertebrates assemblages and physico chemical parameters across a range of water quality in the Region. The different macro invertebrate communities, reflecting water quality can be mildy discerned in the BMWP scores and ASPT values early in the year when flow is higher and water well oxygenated.

However, it becomes apparent at this stage that there is a highly seasonal fluctuation in invertebrate abundance and diversity, a lack of high scoring taxa and some taxa are not widely distributed. Most of the taxa collected rarely score above 3 on the BMWP scale, those that do are scarce. This indicates that some groups may merit further investigation in order to obtain better discrimination. The range of scores from unpolluted through to polluted sites is small illustrated by the similarity of BMWP values and ASPT estimates between R. Machico and R. Frio.

Stressed communities can be discerned, with certain macro invertebrates such as *Physidae* successfully exploiting organically polluted conditions by virtue of their tolerance to these conditions. The BMWP approach , attributing values at family level, with no consideration for abundance is inadequate for Regional biological assessment. A Regional index would have to go beyond family level for certain groups and possibly consider abundance or diversity rather than just presence/absence. Also, some of the endemic or Macronesian species may have indicator value within a regional context. Further discrimination, say to sub-family, tribe or genus may reveal more effective or reliable patterns of macro invertebrate distribution related to water quality leading to a more robust scoring system. This would involve further collection and growing on of selected groups.

Other benefits from such studies are numerous. The freshwater faunal list is continuously being extended. Growing on certain Macronesian and endemic species will greatly improve knowledge upon taxonomy and different life stages. The general ecology and interrelationships of species, trophic levels and human activities within and upon the Region's rivers will be better known. Sites of special scientific interest by virtue of their unique macro invertebrate assemblage can be established. The aquatic macro invertebrate communities in a river thought to be receiving leachates from the Meia Serra Waste Treatment Station have also been studied.

Conclusion

This paper has described preliminary findings from macro invertebrate and chemical samples from 3 rivers in Madeira during 1991. Water quality from clean through to diffuse and heavily polluted urban sites as well as seasonal influences (Spring / Summer) have been examined. Although this project is in the analytical stage, distinct macro invertebrate communities can be discerned between unpolluted and polluted sites and Spring / Summer assemblages, reinforced by chemical analyses. However, preliminary statistical analyses have indicated that many intermediate and clean sites cannot be reliably separated, due to the low diversity of the Regional freshwater fauna and the predominance of low scoring taxa as determined by the monitoring systems presently employed elsewhere. Higher levels of identification and possibly abundance will have to be employed in establishing a representative system and resulting in a greater understanding of the ecological processes within the islands rivers and identify especially valuable sites or sites that need improvement.

ACKNOWLEDGMENTS

CEDRE for financial support through the "Exchange of Experience Programme". MIKE T. FURSE of the Institute of Freshwater Ecology (IFE) River Lab for help with the text. DRª FILOMENA SEABRA and DRª GRAÇA CALADO, Laboratório Regional de Saúde Pública. Técnico Jorge Martins Freitas, LREC. ANTÓNIO DOMINGOS ABREU, Museu Municipal do Funchal, Madeira; DR. PETER BARNARD, British Museum, DR. RUBEN CAPELA and DR. ARTUR SERRANO MONIZ, Faculdade de Ciencias, Universidade de Lisboa; DR PAULO FONTOURA, Universidade do Porto; JOHN BLACKBURN and RALPH CLARKE IFE River Lab, DR. PETE LANGTON UK, DR. GUY MAGNIEZ, University of Dijon and DR. DECLAN MURRAY of University College Dublin.

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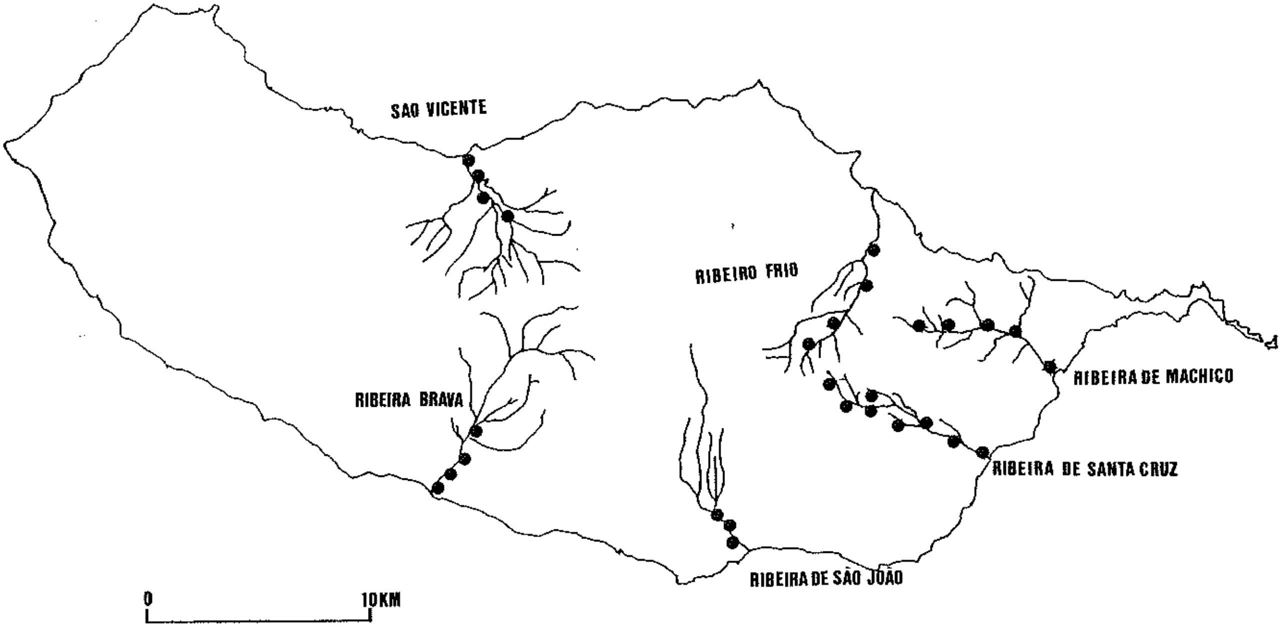
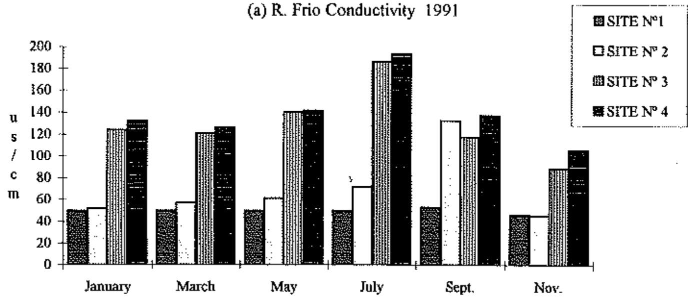
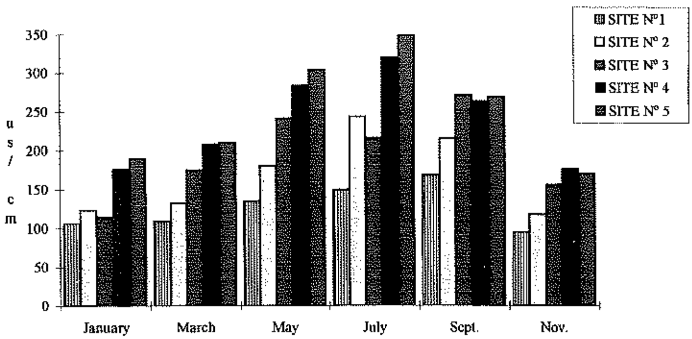


Figure 1 - A map of the aproximate positions of the sites sampled from six rivers during 1991.

(a) R. Frio Conductivity 1991



(b) R. Machico Conductivity 1991



(c) R. São João Conductivity 1991

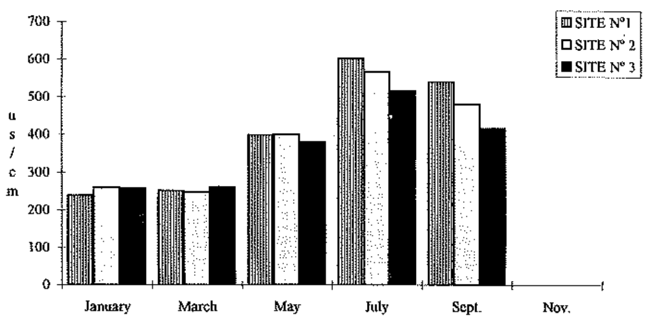
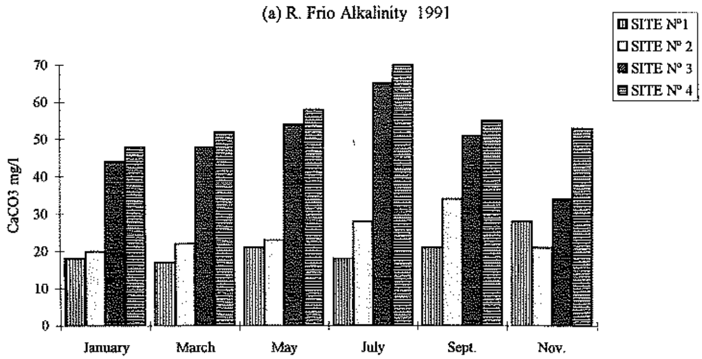
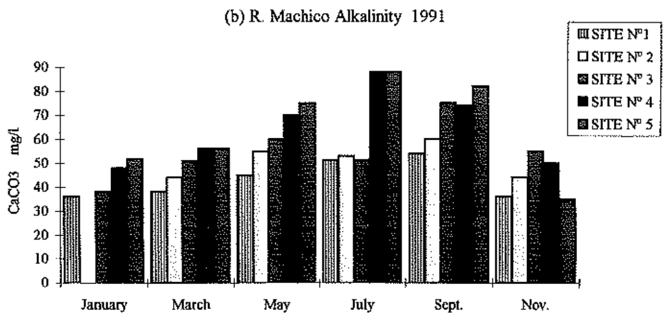


Figure 2 - 1991 Conductivity levels (measured in micro siemens) taken from (a) Ribeiro Frio (b) Ribeira de Machico and (c) Ribeira de São João.





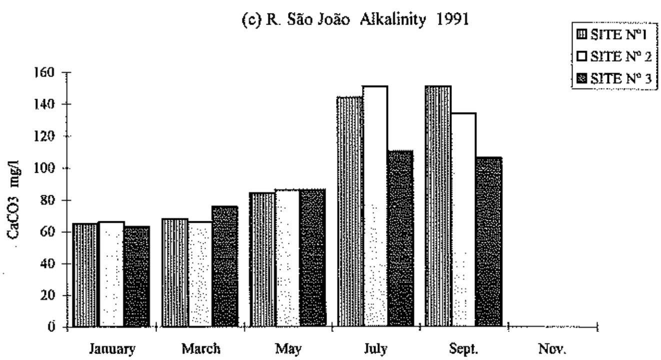


Figure 3 - 1991 Alkalinity readings ($CaCO_3$ mg/l) taken from (a) Ribeiro Frio (b) Ribeira de Machico and (c) Ribeira de São João.

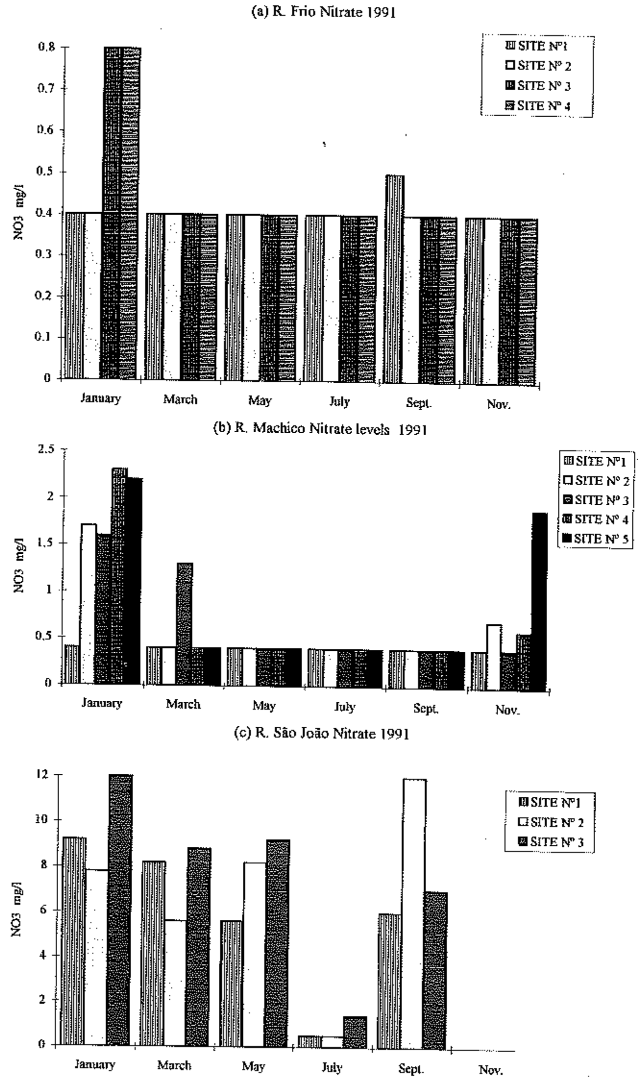


Figure 4 - 1991 Nitrate levels (N-NO_3mg/l) taken from (a) Ribeiro Frio (b) Ribeira de Machico and (c) Ribeira de São João. An arbitrary value of 0.4 mg/l has been given to readings below the 0.5 mg/l level of detection.

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

Figure 5 - The Biological Monitoring Working Party or BMWP System (Biological Monitoring Working Party, 1978).

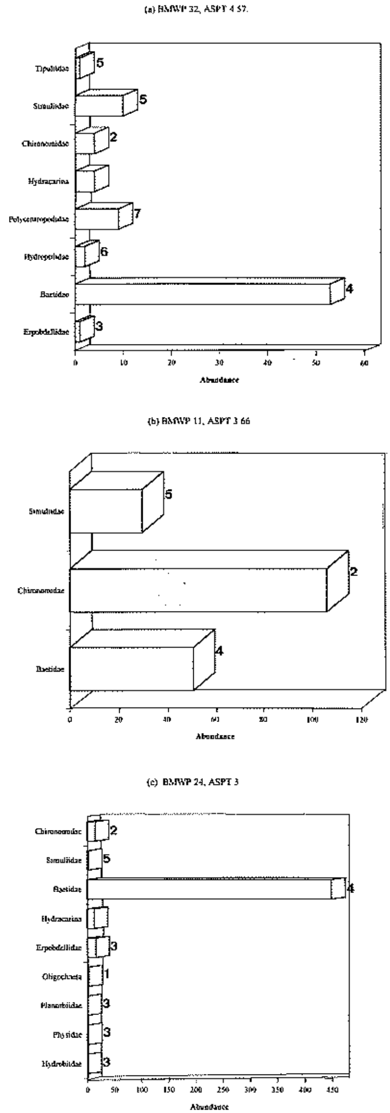


Figure 6a, b and c - The principal macro invertebrate taxa identified to family level, their abundance and attributed BMWP value for R. Frio, sites 1, 2 and 4, Spring 1991. The BMWP site score and Average Score per taxon (ASPT) is given.

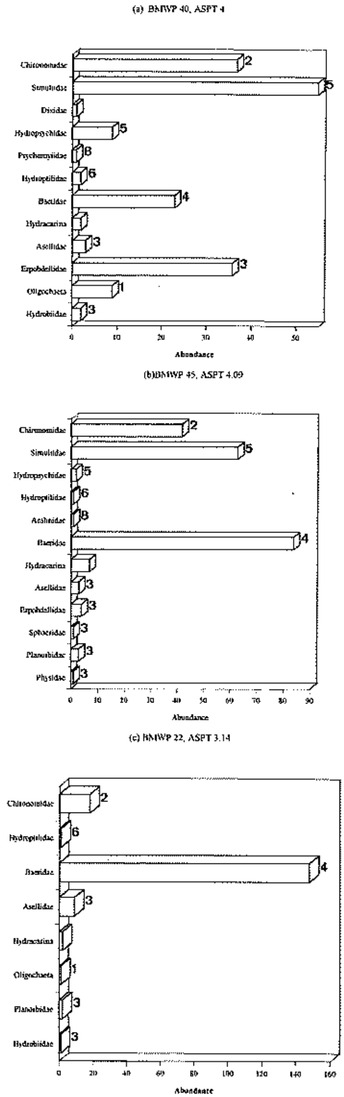


Figure 7 a, b and c - The principal macro invertebrate taxa identified to family level, their abundance and attributed BMWP value for R. Machico sites 1,3, and 5, Spring 1991. The BMWP site score and average score per taxon (ASPT) is given.

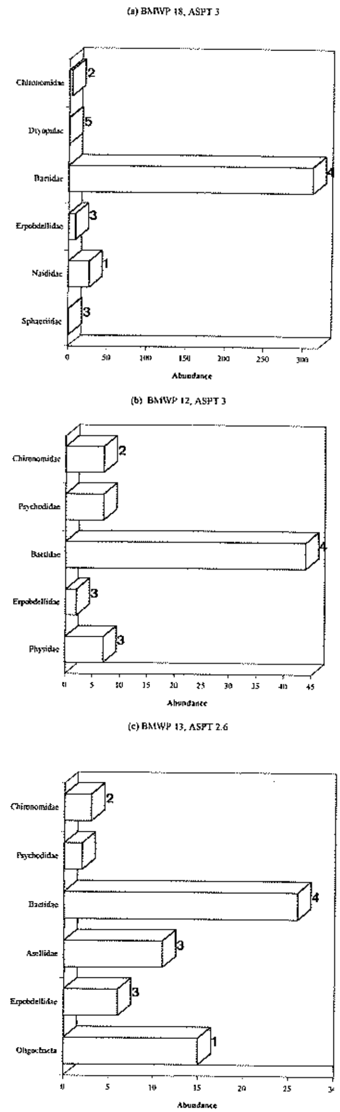


Figure 8a, b and c - The Principal macro invertebrate taxa identified to family level, their abundance and attributed BMWP value for R. de São João sites 1, 2 and 3, Spring 1991. The BMWP site and ASPT is also given.

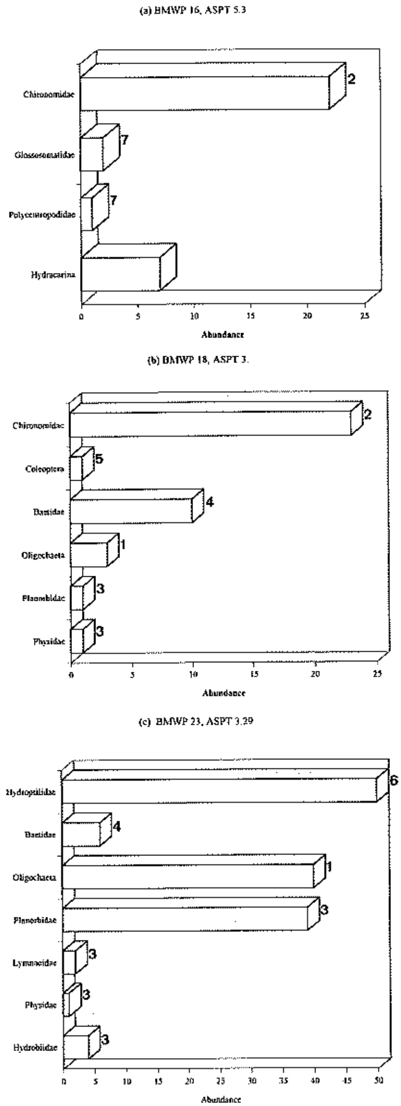


Figure 9a, b and c - The principal m: ro invertebrate taxa identified to family level, Their abundance and attributed BMWP valt for R. Frio sites 1, 2 and 4, Summer 1991. The BMWP site score and ASPT is also given.

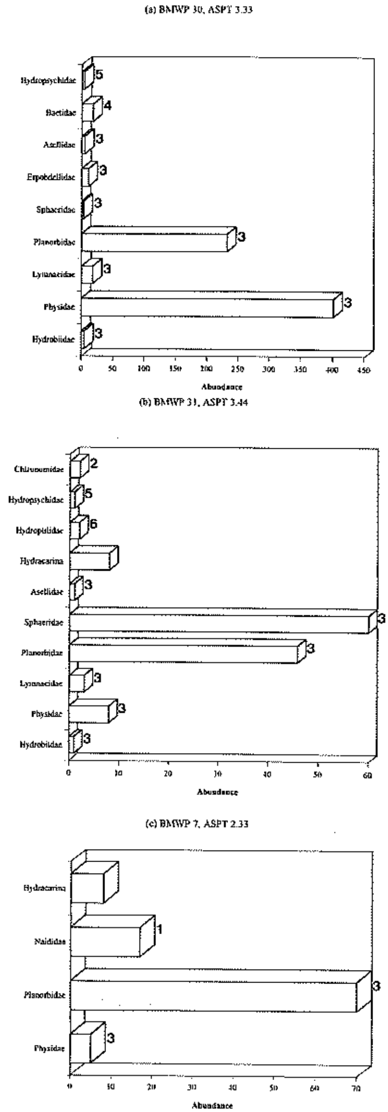


Figure 10a, b and c - The prinicipal macro invertebrate taxa identified to family level, Their abundance and attributed BMWP value for R. de Machico sites 1, 3 and 5 Summer 1991. The BMWP site score and ASPT is also given.

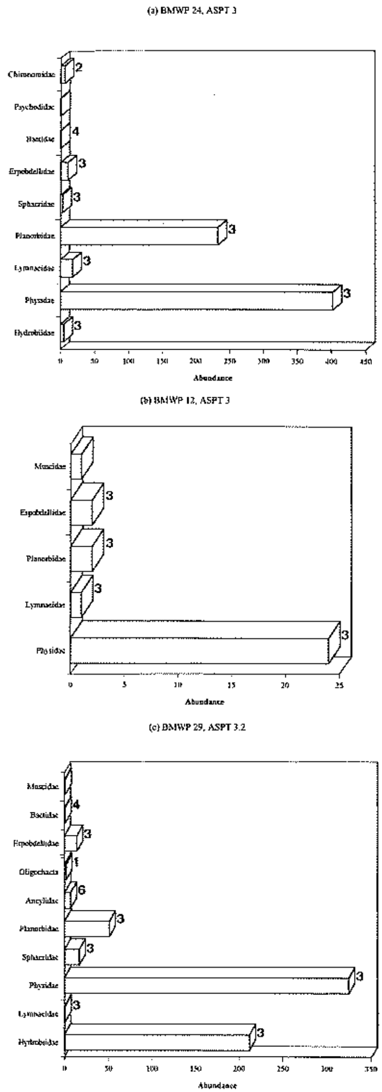


Figure 11a, b and c - The principal macro invertebrate taxa identified to family level, their abundance and attributed BMWP value for R. de São João sites 1, 2 and 3, Summer 1991. The BMWP site score and ASPT is also given.

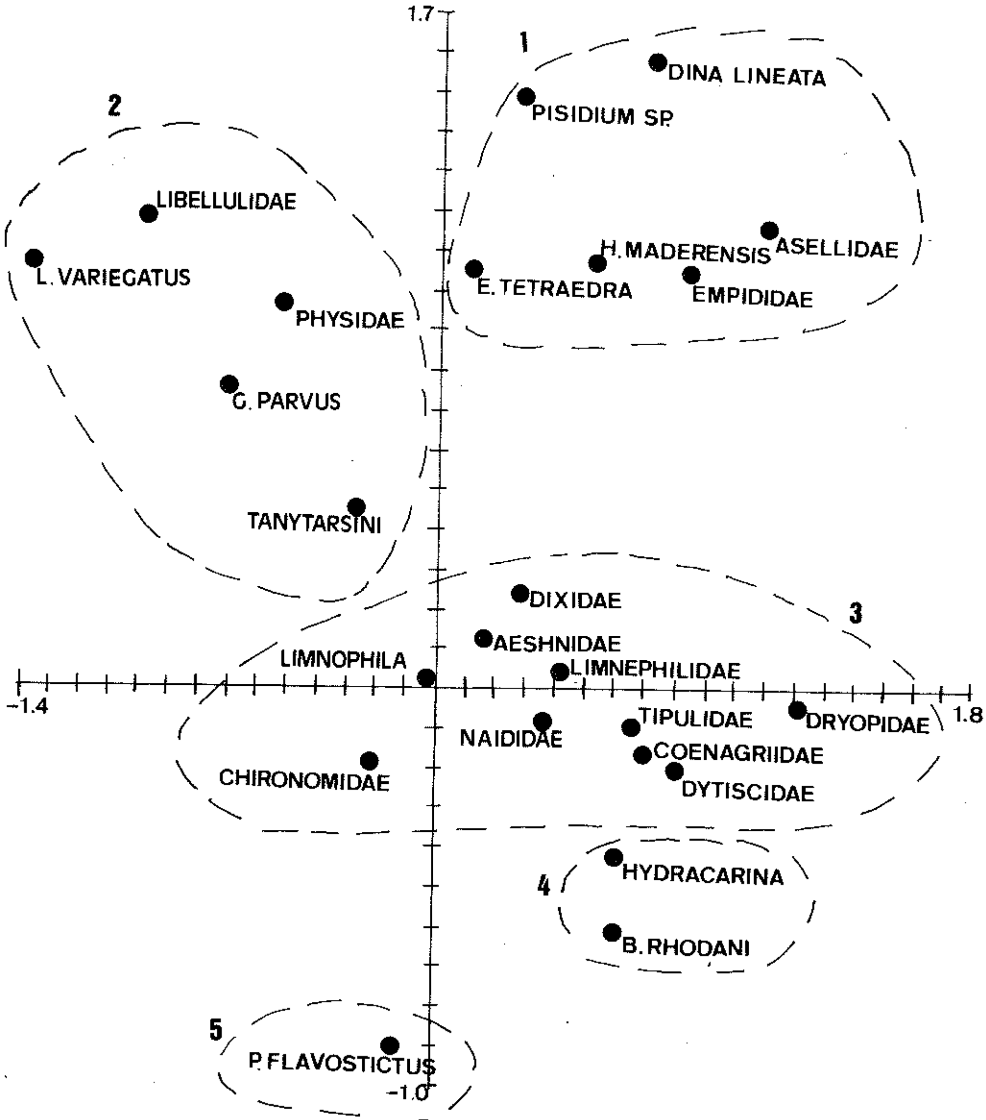


Figure 12 - A preliminary CANOCO ordination plot of the macroinvertebrate taxa from all sites sampled for February and March 1991, carried out at the Institute of Freshwater Ecology in September 1992.

TABLE 1 - A summary of the principal Biological Monitoring Methods currently employed in Europe given in Chronological order.

TITLE	AUTHOR(S)	METHOD	QL./QN*.	BASIS	OBSERVATIONS
(I) Saprobien Systems	Various, based upon work of Kolkowitz & Marsson (1902)	direct observation. of sample	QL. semi-QN	range of FW flora / fauna	requires specialist knowledge, time consuming
(II) Trent Biotic Index (TBI)	Woodiwiss (1964)	total score from table	QL.	FW macro-invertebrates	Does not include abundance/absence.
French Biotic Index	Tuffery & Vernaux (1968)	as above	QL.	FW macro-inverts & systematic units.	Includes levels of abundance.
Chandler Biotic Score	Chandler (1970)	as above	semi-QN.	FW macro-inverts.	abundance/presence absence.
BMWP (UK)	National Water Council (1981)	as above	QL.	as above	presence. Use of Average Score per Taxon (ASPT).
TBI (Denmark)	Andersen,Riget & Sparholt (1982)	as above	QL.	as above	changes made to list, ie Regional
BMWP' (Spain)	Alba-Tercedor Sanchez Ortega (1988)	as above	QL.	as above	changes to taxa ie Iberic Peninsula.
RIVPACS	M.Furse et al 1987- present	predictive		as above	multivar. analysis enviro/chem physical parameters.

* QL. = Qualitative.
QN. = Quantitative.

TABLE 2 - A list of the principal water analyses carried out at the Regional Public Health Laboratories.

pH	pH uints	0-14
Conductivity	micro seimens	us /cm
Alkalinity (i)	CaCO3	mg / l
Alkalinity (ii)	phenolphtalein	mg / l
Chloride	Cl-	mg / l
Sulphate	SO4 - -	mg / l
Nitrate	NO3 -	mg / l
Nitrite	NO2 -	mg / l
Ammonia	NH3	mg / l
Total Hardness		od
Calcium	Ca ++	mg / l
Magnesium	Mg++	mg / l
Phosphate	PO4- - -	mg / l
Iron	Fe ++	mg / l
Dissolved Oxygen	mg /l	mg / l

TABLE 3 - Levels of determination employed in macroinvertebrate samples. The asterisk indicates groups that could be easily determined beyond the described level due to the depauperate nature of the fauna.

GROUP	LEVEL
Trichoptera	genus / species*
Ephemeroptera	genus / species*
Odonata	genus / species*
Coleoptera	genus / species*
Mollusca	genus / species*
Crustacea	family*
Hemiptera	genus*
Diptera	family / sub-family / tribe*
Hydracarina	presence