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An investigation of macrophyte and macroinvertebrate communities in lowland sites on the rivers of Milltown (Muckno Mill) lake catchment, Co. Monaghan, Ireland

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Introduction

The requirements of the Water Framework Directive (CEC 2000) have precipitated many national (Kelly-Quinn et al. 2005) and pan-European (Brabec & Szoszkiewicz 2006) studies on the interactions between biological elements and physical and chemical water quality parameters. Kelly-Quinn et al. (2005) in a study with all sites of "high" ecological status, found that hardness and slope explained most of the variance in the 4 biological communities surveyed (macrophytes, macroinvertebrates, phytobenthos, fish). Ferreol et al. (2008) identified geographical position as a variable that influences macroinvertebrate species composition, as did Murphy & Davy-Bowker (2005) who also highlighted altitude. For macrophyte communities, Grasmuck et al. (1995) highlighted geology, while the STAR macrophyte project highlighted sampling period and shading (Brabec & Szoszkiewicz 2006).

Macrophytes and macroinvertebrates are both used extensively to assess water quality, and when used together can provide a larger picture of water quality in a catchment (Caffrey 1987). Both communities, however, may be responding to different pressures (Kelly 1997). Both the macrophyte and macroinvertebrate water quality indices suggest that much of the Milltown Lake catchment is affected by eutrophication, but these indices disagree on which sites are most or least impacted (Wynne & Linnane 2007). In line with current research, our study employs appropriate multivariate statistics to explain variation in the sample communities. Because the study is restricted to one small catchment (34 km^2), variables such as hardness, altitude, geology, and geographical position will lack gradient when compared to the pan-European or national scales in those projects. Analyses were carried out to ascertain if the variance caused by water quality parameters associated with localised, anthropogenic factors could be more evident.

Key words: macrophyte, macroinvertebrate, water quality

Materials and methods

Chemical and physico-chemical data were collected from all sites during each of the biological surveys. Dissolved oxygen (DO), pH and conductivity were measured in the field electrometrically. Samples were collected for ortho-phosphate (P) and analysed using the molybdate method of Murphy & Riley (1962). Samples were also collected for a 5-day Biological Oxygen Demand (BOD) and analysed by Winkler titration (APHA 1995). Site physical characteristics were noted *in situ*.

Macroinvertebrate surveys were carried out on 26 sites across the catchment in May 2006 following periods of normal flow. Riffle areas were sampled using three 1-min kicks with a hand net and subsequent stone washes. Collected samples were identified to the levels required by the Irish Q-value index (Flanagan & Toner 1972, Toner et al. 2005). Macrophyte surveys were carried out during early July 2006 following periods of normal flow. River stretches of 100 m were surveyed, coinciding as closely as possible with macroinvertebrate sampling sites. Surveys followed the guidelines set out by the British Mean Trophic Rank (MTR) method (Holmes 1999).

During data analysis categorical parameters (flow type, shading, dominant substrate type, stream order, and presence/absence of a bridge) were coded, and continuous physical and chemical parameters (pH, DO, BOD, P, conductivity, sampling depth, and wet width) were log transformed. For correlation analyses, counts of macroinvertebrates were grouped (Group A–Group D) according to the trophic response groupings suggested in the Q-value index. Categorical abundance values for macrophytes were coded; species were then grouped according to the trophic response weighting given to each species in the MTR (Group 1/2–Group 7/8). Species from both communities were grouped to reduce the number of 0 values in the analysis. Correlations were carried out on the data using SPSS v.15. For the multivariate analyses macroinvertebrate counts were $\log(x + 1)$ transformed, and abundance categories for macrophytes were coded. Multivariate analyses were carried out using Canoco 4.5 (ter Braak & Smilauer 2002).

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Results

Mean P concentration for the sites surveyed was 0.036 ± 0.005 mg/L; mean DO concentration was 9.8 ± 0.42 mg/L; mean BOD concentration was 3.54 ± 0.32 mg/L; mean conductivity was 152.08 ± 7.87 mS/cm; and pH ranged from 7.04 to 8.76.

Detrended correspondence analysis (DCA) carried out on the macoinvertebrate community calculated short community composition gradients; therefore, linear ordination methods (Principal components analysis, PCA) were employed. The first 4 axes of the PCA (Fig. 1a) explained 72.2 % of the observed variance. The first PCA axis explained 34.7 % of the variance and was positively correlated with P and negatively correlated with conductivity. The second PCA axis is dominated more by physical site characteristics than chemical ones. This axis explains 16.8 % of the variance and is dominated by wet width, the presence or absence of a bridge, and is negatively correlated with substrates dominated by sand and positively correlated with substrates dominated by silt.

The DCA carried out on the macrophyte community suggested that unimodal ordination methods (Canonical correspondence analysis, CCA) were appropriate. The CCA (Fig. 1b.) for the macrophyte community explains 60.8 % of the total variance. The first axis, explaining 20.6 % of the variation, is dominated by the physical attributes at the site. This axis is most correlated with wet width, the presence of bedrock, and is negatively correlated with first-order streams. The second axis, which explains a further 15.4 % of the variation, is dominated by site chemistry and is positively correlated with P, BOD, and DO.

Spearman rank correlations were performed on grouped species counts for macroinvertebrates and abundances for macrophytes. The 2 groups of species representing the most sensitive macroinvertebrates were significantly, positively correlated with P: Group A, which included most *Plecoptera* and *Ephemeroptera* ($r = 0.438$, $p < 0.05$) and Group B, which included some *Plecoptera*, *Ephemeroptera* and all the cased *Trichoptera* ($r = 0.64$, $p < 0.01$). Species diversity indices calculated also showed an increase in species diversity with increasing P: Simpson's ($r = 0.648$, $p < 0.01$), Shannon's ($r = 0.631$, $p < 0.01$) and Shannon Evenness ($r = 0.713$, $p < 0.01$). Group B showed a significant, positive correlation with DO ($r = 0.524$, $p < 0.01$). Group D macroinvertebrates, which included *Asellus* and most *Hirudinea* were significantly, negatively correlated with P ($r = 0.539$, $p < 0.05$) and DO ($r = –0.415$, $p < 0.05$). Group D was also significantly, positively correlated with conductivity ($r = 0.448$, $p < 0.05$). Group 1/2 macrophytes, a composite group of species with low MTR trophic scores, were significantly negatively correlated with both P ($r = –0.497$, $p < 0.05$) and DO ($r = –0.422$, $p < 0.05$), while Group 3/4 was significantly, positively correlated with BOD ($r = 0.429$, $p < 0.05$).

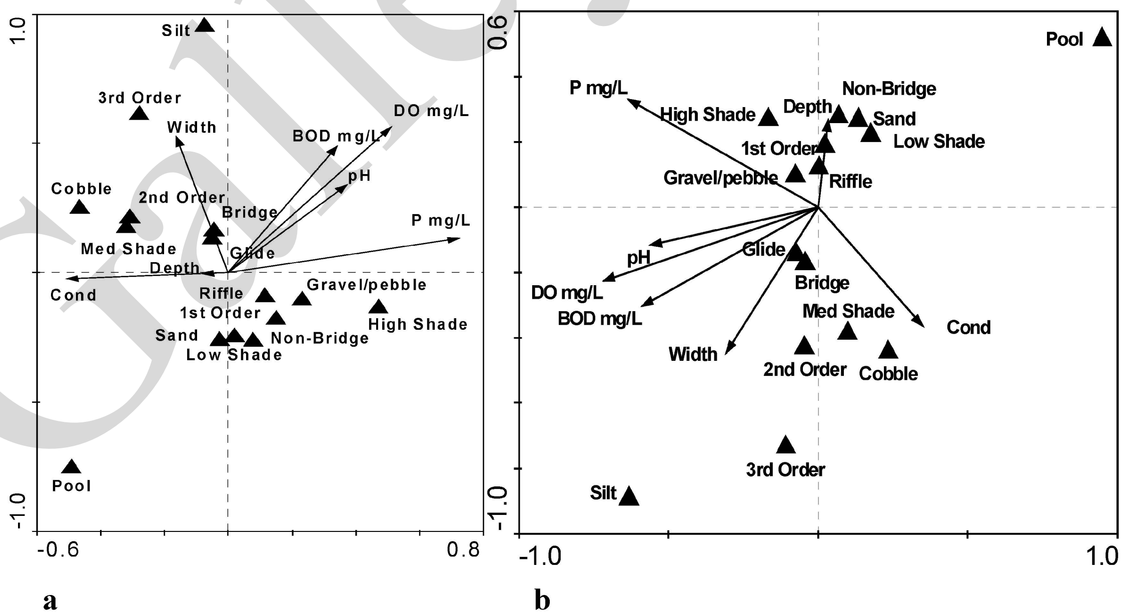

Fig. 1. (a) PCA of macroinvertebrate community. (b) CCA of macrophyte community. (Coded categorical variables are represented by ▲, continuous variables are represented by arrows).

Discussion

The mean P concentration for the catchment (Table 1) is just above the guideline limit (0.03 mg/L) for an "unpolluted" site in the Irish Phosphorus Regulations (SI 258/ 1998). The mean DO concentration is in keeping with the guidelines in the Q-value Index that pristine sites should have, a DO close to 100 % saturation at all times, but the minimum concentration recorded was 6.8 mg/L, which is closer to the concentration suggested for a "seriously polluted" site.

Ordination analyses carried out on both the macroinvertebrate and macrophyte communities show that each community is governed by a mixture of the physical and the chemical characteristics at each site. In the case of macroinvertebrates, the axis dominated by chemical characteristics (P and conductivity) best explained the variation in the community. Site physical characteristics were of secondary importance. These results differ from some studies of species-environment relationships, including Murphy & Davy-Bowker (2005) who found that physical characteristics were among the most powerful explanatory variables for macroinvertebrate communities in Britain. However, Azrina et al. (2006) and Skoulikidis et al. (2008) also found conductivity to be important. When the community was analysed with regard to trophic response (grouped species), they found that the most sensitive species were positively correlated to P. Correlations between P and the diversity indices used show that increases in P resulted in increased species diversity. It would appear that P concentrations were not high enough to discourage members of the *Plecoptera* and *Ephemeroptera* from the sample sites. An indication that the observed stress in the community might have been due to low DO concentrations is that the second most sensitive group was positively correlated with DO and the least sensitive group showed a negative correlation. Such findings are in line with the expected response of macroinvertebrates to DO (Toner et al. 2005).

Table 1. Summary of chemical parameters for Milltown Lake catchment.

	Mean ± SE	Min	Max
Ortho-phosphate mg/L	0.036 ± 0.005	0.002	0.099
Dissolved Oxygen mg/L	9.8 ± 0.422	6.8	15.85
BOD mg/L	3.54 ± 0.32	1.19	8.26
Conductivity mS/cm	152.08 ± 7.87	99.5	260
pH	7.66 ± 0.08	7.04	8.76

Variance in the macrophyte community was best explained by site physical characteristics, showing a gradient from narrow, first-order streams to wider, deeper streams. A significant proportion of the remaining variation was explained by site chemical characteristics (P, BOD, and DO). The importance of this gradient between upstream and downstream sites was also found by Grasmuck et al. (1995); Triest (2006) also found correlations with width. When grouped according to trophic response, the most sensitive group from the macrophyte community was negatively correlated with P and DO concentrations. Negative correlation between P and the most sensitive macrophyte species were also noted by Dawson et al. (1999).

Conclusions

Our results show that the effect of physical habitat on biological communities explains much of the variance observed in both assessed communities. Both communities also showed responses to the chemical parameters at each site, with the most sensitive macroinvertebrates affected by decreasing DO concentrations and the macrophytes most affected by high P concentrations. Such differing responses to stressors may help explain the conflicting results provided by both indices used and provide greater insight into the pressures operating on a particular system.

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