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Review paper

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A review of the use of macroinvertebrates for monitoring the quality of lotic freshwaters in the UK and early stages of development in Poland

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Abstract

The use of benthic macroinvertebrates has become an important tool for monitoring the quality of freshwaters. A review is given of the development of the Biological Monitoring Working Party scheme in the United Kingdom (BMWP-UK) and how this has been modified in Poland (BMWP-PL). Methodologies are also described showing how basic data sets collected for the BMWP scheme can be used for the assessment of flow conditions and to identify sites for special conservation measures.

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INTRODUCTION

Methodologies have been devised in the UK, using freshwater macroinvertebrates to monitor water quality, to assess the quality of the habitat for conservation and to index river flow for setting hydroecological objectives. Some of these are being developed in Poland. This paper reviews these methods and makes comparisons between the developments in the UK and early stages in Poland.

GENERAL QUALITY ASSESSMENT (GQA)

The UK has used the General Quality Assessment (GQA) since 1988 to monitor the water quality of rivers and canals throughout England and Wales and produces a report every three years. 7,000 sampling sites are assessed for: chemical status; biological status; nutrient levels; aesthetic water quality.

Chemical and nutrient monitoring is undertaken at each site every month and grades are assigned to the sites based on three years of data to reduce the effects of variable conditions. Chemical GQAs are graded A-F on dissolved oxygen; Biological Oxygen Demand (BOD) and ammonium (NH_3). Nutrient GQAs are graded 1-6 on the basis of levels of nitrate and phosphate in the water. Aesthetic GQAs are graded 1-4 on four parameters; litter, oil, colour, odour. Biological GQAs are graded A-F using the occurrence of macroinvertebrates.

BIOLOGICAL GQA – BIOLOGICAL MONITORING WORKING PARTY

The Biological Monitoring Working Party (BMWP) was set up in 1976 in the UK (Chester 1980) to develop a biotic system to assess the quality of rivers and canals. It recommended that invertebrate families should be allocated a score of 10 – 1 on the basis of their tolerances to pollution and enumeration should be discarded. Sites are sampled by a three-minute kick/sweep with a pond net of a standard size. All major habitats are included and sampled in proportion to their occurrence. Sampling is undertaken at least twice a year as the phenology of different aquatic invertebrates can vary (Table 1). Some taxa may not be represented in the aquatic stage during the spring and some in the autumn causing variations in the BMWP scores for these two seasons. The data are then averaged, preferably over three years, to provide the BMWP score for a site. Identification of the invertebrates is to family level, and the least tolerant families are given the highest scores. Examples of invertebrate family tolerance scores are seen in Table 2. The BMWP score is the sum of the individual family tolerance scores, and it is implicit that the higher the score the better the quality

Table 1

BMWP score for samples from some Bedfordshire UK rivers in 2000. UK Environment Agency unpublished observations

River	Spring		Autumn	
	BMWP	ASPT	BMWP	ASPT
Ouzel	111	4.4	60	3.8
Great Ouze	174	5.4	166	5.5
Ivel (i)	113	4.9	114	5
Campton Brook	77	4.8	42	4.2
Ivel (ii)	95	4.5	126	4.8
Hiz	88	4.6	113	4.7
Bromham Brook	89	4.7	85	4

Table 2

BMWP – Examples of Invertebrate Family Tolerance Scores

Group	1	2	3	4	5	6	7	8	9
Score	10	8	7	6	5	4	3	2	1
	Siphlonuridae Leuctridae Sericostomatidae	Lestidae	Nemouridae Caenidae	Unionidae	Corixidae Dytiscidae	Baetidae Sialidae	Lymnaeidae Hirudidea	Chironomidae	Oligochaeta (class)

of the water. This total score is then divided by the number of taxa to produce the Average Score Per Taxa (ASPT) which is independent of sample size. A larger sample is likely to have more families and thus inflate the BMWP score if this is not standardised in some way. Examples of the BMWP scores for two Bedfordshire rivers are seen in Table 3.

Table 3

BMWP/ASPT scores of two contrasting rivers from Bedfordshire, UK

<table>
<tr><td colspan="10">River Great Ouse, near Kempston</td></tr>
<tr><td colspan="2">Description</td><td colspan="8">Average width – 17 m; average depth – 2 m; substrate 1-10 cms. 30% cover of submerged vegetation. 1 m wide marginal emergent vegetation with accumulation of silt. Adjacent land use - grassland/woodland.</td></tr>
<tr><td>Date</td><td>30/11/05</td><td>Altitude</td><td>30 m</td><td>Number of taxa</td><td>17</td><td>BMWP</td><td>88</td><td>ASPT</td><td>5.3</td></tr>
<tr><td colspan="10">Elstow Brook, Wooton near Bedford</td></tr>
<tr><td colspan="2">Description</td><td colspan="8">Tributary of the river Great Ouse; average width – 2 m; average depth – 0.25 m; substrate fine silt supporting good cover of submerged and emergent vegetation; adjacent land use – rough grass and scrub.</td></tr>
<tr><td>Date</td><td>25/05/03</td><td>Altitude</td><td>40 m</td><td>Number of taxa</td><td>10</td><td>BMWP</td><td>37</td><td>ASPT</td><td>3.7</td></tr>
</table>

The BMWP – PL has evolved only since 2000 from the British BMWP and whereas the main concept is the same, the allocation of scores has differed (Kownacki et al. 2004). Variations in the geographical ranges of families and the fact that Poland is part of a large land mass compared to the island status of the British Isles (which thus has a much smaller fauna) has required the establishment of a distinctive list of family tolerances for the BMWP – PL (Table 4). The Polish system puts much more emphasis on the use of quantitative sampling measures, and data from both qualitative and quantitative sampling are fed into the analysis of river quality. As well as the estimation of BMWP scores, the Polish system calculates the Diversity Index using the Margalef formula. If the classes of river derived from these two calculations differ, then the lowest class is selected. If the two methods differ by two classes, then an average is taken. In the UK, it has been found that a qualitative approach is sufficiently robust and more time effective and greater rigour has been developed using computer modelling. The BMWP methodology has been developed essentially to monitor changes in fauna as a result of organic loading. Many other factors also may influence the distribution of freshwater invertebrates. The River Invertebrate Prediction and Classification System (RIVPACS) has been developed to address these problems (Wright et al. 1993) and was first used by the UK Environment Agency for the 1990 River Quality Survey. BMWP scores can be predicted for three seasons (spring, summer, autumn) on the basis of eight environmental variables: distance from the source (km); mean substrate type (phi); altitude (m); discharge category ($m^3 s^{-1}$); mean water width (m) and depth (m); latitude (°N) and longitude (°W). These are used to produce expected BMWP/ASPT scores which are then compared to actual scores from sampling. The actual/expected ratios give indices of ecological quality (EQI). These are then assigned a grade of A to F with A representing the highest quality.

Table 4

Comparison of Tolerance Scores between BMWP-UK and BMWP-PL

Family	UK	PL	Family	UK	PL
Siphlonuridae	10	7	Perlidae	10	8
Phryganeidae	10	-	Odontoceridae	10	10
Ameletidae	-	10	Potamanthidae	-	7
Bythyniidae	-	6	Tipulidae	5	5
Baetidae	4	6	Hydrobiidae	3	5
Erpobdellidae	3	3	Chironomidae	2	3

THE LOTIC INVERTEBRATE INDEX FOR FLOW EVALUATION (LIFE)

This technique is based on the knowledge that the distributions of many freshwater invertebrates have strong relationships with current velocities or flow ranges. Extence et al. (1999) proposed The Lotic Invertebrate Index for

Flow Evaluation which uses standard Environment Agency (EA) sampling methods and information on invertebrate preferences noted by a wide range of authors. Freshwater invertebrate species are allocated to one of six flow groups as shown in Table 5. Although some species are found in a wide range of flows, they are allocated to their main ecological preferences. Species abundances can also be incorporated into the LIFE method using standard EA classes shown in Table 6. The LIFE calculation involves both estimated abundances and flow groups to produce individual flow scores as in Table 7. Where $\sum fs$ is the sum of individual taxon flow scores for the whole sample, and n is the number of taxa. High LIFE scores equate to high flows. At times species identification is not available. It is possible, though with less precision, to use data at the family level.

Table 5

Macroinvertebrate Flow Groups (Extence et al. 1999)

I	Taxa primarily associated with rapid flows >100cm s^{-1}
II	Taxa primarily associated with moderate to fast flows 20-100 cm s^{-1}
III	Taxa primarily associated with slow or sluggish flows <20 cm s^{-1}
IV	Taxa primarily associated with flowing (usually slow) and standing waters
V	Taxa primarily associated with standing waters
VI	Taxa frequently associated with drying or drought impacted sites

Table 6

Standard EA macroinvertebrate abundance categories

Category	A	B	C	D	E
Estimated abundance	1-9	10-99	100-999	1000-9999	10 000+

Table 7

Scores (*fs*) for different abundance categories of taxa associated with flow groups I-VI (Extence et al. 1999)

Flow groups		Abundance categories			
		A	B	C	D/E
I	Rapid	9	10	11	12
II	Moderate/fast	8	9	10	11
III	Slow/sluggish	7	7	7	7
IV	Flowing/standing	6	5	4	3
V	Standing	5	4	3	2
VI	Drought resistant	4	3	2	1
The index is then calculated as: $LIFE = \sum \frac{fs}{n}$					

Further work is required on watercourses that periodically dry up and on small streams that are not regularly monitored for flow. However, there are opportunities for linking the method to habitat quality assessment (low flows are particularly linked to poor habitat quality) and may be associated with other techniques including the river habitat survey methods (National Rivers Authority 1993). It may be possible, ultimately, to provide threshold LIFE scores needed to maintain invertebrate diversity and to link this with water resource licensing.

CLASSIFICATION OF COMMUNITIES FOR CONSERVATION

A new indexing method which enables riverine and still water sites to be selected for special conservation methods is described by Chadd and Extence (2004). The Community Conservation Index (CCI) incorporates species richness as well as rarity and has been used in the designation of Sites of Special Scientific Interest (SSSIs) and candidate Special Areas of Conservation (cSAC's) as well as for legal purposes in public enquiries. It can also be used as a management tool for the conservation of habitats of high quality. It indicates sites that have exceptionally diverse or unusual invertebrate populations as well as those containing rare species. Species are given a Conservation Score based on their national or local conservation status from a score of 10 for species that are nationally endangered to a score of 1 for species occurring in 50 – 100% of all samples from similar habitats (Table 8). A second score, the Community Score, is derived from the BMWP score, using UK Environment Agency data, where a Community Score of 9 or 10 is allocated for communities with a BMWP score of more than 201 and a Community Score of 1 is equivalent to a BMWP score of 1 – 50. However, the Conservation Score for each species is reviewed and the highest value may be taken to derive the Community Score in order to give special status to rare species. Thus from Table 9, if the highest taxa Conservation Score is 7 the Community Score will be given the score of 7 even if the BMWP score only warrants a lower score. A Community Conservation Index is then calculated from these by averaging the Conservation Scores and multiplying by the Community Score.

$$\text{CCI} = \text{Average Conservation Score} \times \text{Community Score}$$

The threshold level of the Conservation Index still has to be established before the site is designated as one for special conservation consideration. The experience of the UK EA suggests that any site that has an index in excess of 20 should be given special status. Between indices of 10 – 20 sites would have some value but would not receive high priority. Examples of the Community

Conservation Indices for two contrasting rivers in Bedfordshire are seen in Table 10.

Table 8

Conservation Scores for freshwater invertebrate species (Chadd and Extence 2004)

Score	Definition
10	RDB 1 Endangered
9	RDB2 Vulnerable
8	RDB3 Rare
7	Notable (but not RDB status) or Regionally very Notable
6	Regionally notable
5	Local
4	Occasional – Species not in categories 10-5, which occur in up to 10% of all samples from similar habitats
3	Frequent – Species which occur in 10-25% of all samples from similar habitats
2	Common – Species which occur in 25-50% of all samples from similar habitats
1	Very common – Species which occur in 50-100% of all samples from similar habitats

Table 9

Community Score Categories (Chadd and Extence 2004)

Com. Score	15	12	10	7	5	3	1	0
BMWP	301+	251-300	201-250	151-200	101-150	51-100	1-50	0
Highest Con. Score	10	9	8	7	5 or 6	3 or 4	1 or 2	Scoring Taxa absent

Table 10

Community Conservation Indices for two contrasting Bedfordshire UK rivers

River Ivel at Langford Mill near Biggleswade, Bedfordshire		**The Riddy at Cowslip Meadow, Luton, Bedfordshire**	
The river is a major tributary of the river Great Ouse. At Langford Mill the river is 5m wide and has an average depth of 0.75m. The substrate size varies from 2-8cm. There is a wide band of marginal vegetation and the land use is mostly pasture.		The stream is a minor tributary of the river Lea and regularly dries out in the summer. The stream is 1m wide and has an average depth of 0.05m. The substrate is silty and the land use is rough grass of a local nature reserve.	
Date	October 2003	Date	October 2003
Number of species	21	Number of species	17
Sum of Conservation Scores	41	Sum of Conservation Scores	23
Average Conservation Score	2	Average Conservation Score	1.4
BMWP Score	94	BMWP Score	73
Highest Conservation Score	7	Highest Conservation Score	3
Community Score (BMWP)	4	Community Score (BMWP)	4
Community Score (Highest Conservation Score)	7	Community Score (Highest Conservation Score)	3
Community Conservation Index is: $2 \times 7 = 14$ a fairly high conservation value site OR $2 \times 4 = 8$ a moderate conservation value site		Community Conservation Index is: $1.4 \times 3 = 4.2$ a site of little or no conservation value OR $1.4 \times 4 = 5.6$ a site of little or no conservation value	

SUMMARY

These three methodologies, utilising the same data sets, are invaluable tools in the evaluation and protection of aquatic environments. Studies of freshwater macroinvertebrate communities continue to offer opportunities for the assessment of the quality of aquatic habitats and their management requirements. The increasing experience of the use of these techniques by ecologists throughout Europe will inevitably lead to improvements in their application and will generate still more new approaches.

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