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Implications of taxonomic modifications and alien species on biological water quality assessment as exemplified by the Belgian Biotic Index method

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Abstract

In this paper, some important problems related to taxonomic resolution in water quality assessment by means of macroinvertebrates are discussed. Most quality indices based on macroinvertebrates only require identification up to genus or family level. Although this can be seen as a practical trade-off between taxonomic precision and time constraints and financial resources, it can result in biased assessment scores for certain stream types. An additional difficulty of identification levels other than species is caused by possible changes in taxonomy over time. A given genus may indeed have been split up into two or more genera or a species could be assigned to a different genus. These changes may alter biotic index values calculated over time, due to a change in number of taxa or replacement of one taxon by another one having a different tolerance class. An additional problem is caused by the invasion of exotic species. The genus *Corbicula* for instance is currently invading Belgian watercourses in increasing numbers. Since no Belgian Biotic Index (BBI) tolerance class is defined for *Corbicula*, this may cause inconsistencies in index calculations as well. In order to eliminate these, a semi-fixed taxa list, including a tolerance class for each taxon, for BBI calculation is proposed.

Introduction

In biomonitoring, two approaches can be distinguished: the bioconservation approach, where biodiversity and species conservation are the key incentives for sampling an aquatic habitat, and the bioassessment approach, where the focus is on water quality assessment and hence, insight in the biological community is a means rather than a goal. The former approach implies a species-level identification of the sampled organisms, while the latter usually involves a trade-off between a higher level of identification with lower costs but a less precise outcome, and a species-level identification with higher costs but a higher precision. The objectives of a sampling campaign should therefore be decisive for the choice of identification level. In this paper, some problems related to taxonomic resolution in water quality assessment by means of macroinvertebrates are discussed.

Various authors recommend identification to species level to ascertain a detailed insight in the community composition, avoiding information loss due to lumping of taxa, and showing a strong assemblage–environment relationship (e.g. Resh & McElravy, 1993; Stubauer & Moog, 2000; Verdonschot, 2000; Lenat & Resh, 2001; King & Richardson, 2002; Adriaenssens et al., 2004). On the other hand, species identification is time-consuming and expensive. On top of that, information loss when identifying to genus or even family level is often small, and according to several authors it is therefore not necessary to descend to the species level (e.g. Warwick, 1988; Bowman & Bailey, 1997; Ghetti, 1997; Olsgard et al., 1998; Dolédec et al., 2000; Gayraud et al., 2003). Another problem associated with species level identifications is the increasing uncertainty that arises with an increasing level of detail. Ellis (1985) acknowledged this when defining taxonomic sufficiency as the level to which the organisms should be identified in order to balance the need to indicate the biological community versus accuracy of the identifications. When deciding upon the taxonomic level, all aspects mentioned above should be taken into consideration. According to Guérold (2000) and Roach et al. (2001) family level is sufficient for detecting perturbations on the macroinvertebrate community, but a more detailed level of identification is necessary for ecological interpretation. Williams & Gaston (1994) proposed the use of higher-taxon categories as surrogates for species in rapid biodiversity surveys. Karr & Chu (1999) consider genus level to be sufficient for developing a multimetric index and also family level to be acceptable in case of limited time and/or financial resources.

Whatever taxonomic level is used for a biotic water quality index, the level should be fixed with the method description because (1) many methods can only be calculated when using the predefined level, e.g. when taxon-specific tolerance values are defined and (2) taxonomic level can affect index calculation (e.g. Guérold, 2000; Schmidt-Kloiber & Nijboer, 2004).

An additional difficulty with identification levels other than species, however, is caused by possible changes in taxonomy over time, giving rise to inconsistencies in index calculation. A given genus may be split up into two or more genera or a species can be assigned to a different genus. These changes may alter the value of the biotic indices calculated based on the given taxa, respectively because the number of taxa (of a level higher than species) has changed or a taxon is replaced by another one (having a different tolerance class). This is demonstrated by a simple example of Belgian Biotic Index (BBI) calculation of a virtual sample.

Similar problems are due to the invasion of exotic species. Newly occurring taxa raise discussions whether or not to include them in the existing index, which may imply defining a tolerance class for the new taxon, as used in most biotic index methods. This problem has risen for at least one exotic genus in Belgium, as will be discussed later.

Calculation of the BBI

The BBI method is a standardised method to assess biological quality of watercourses based on the macroinvertebrate community. The method was proposed by De Pauw & Vanhooren (1983) and has been adopted as a standard method by the Belgian Institute of Normalisation (IBN, 1984). Since its first publication, the method has been extensively used to assess water quality in Belgium but also abroad (De Pauw & Hawkes, 1993). Since 1989, the Flemish Environment Agency (VMM) assesses around thousand sites throughout Flanders (Belgium) each year by means of the BBI.

The BBI combines characteristics of the indices proposed by Woodiwiss in the UK (1964, Trent Biotic Index) and Tuffery and Verneaux in France (1968, Indice Biotique). The method is based on aquatic macroinvertebrates sampled with a standard handnet, as in the method of Woodiwiss (1964) and the calculation of the biotic index using the table as proposed by Tuffery & Verneaux (1968). Some adaptations were made concerning the sampling method and the taxonomic level of identification. Table 1 summarises the taxonomic levels of identification for the BBI as proposed by De Pauw & Vanhooren (1983). Only taxa of which at least two individuals are found in the sample, are taken into account. The calculation of the BBI is based on a combination of the highest tolerance class encountered, the class frequency within the highest tolerance class and the total number of taxa (Table 2). For instance, a sample containing 9 taxa, 2 of which having a tolerance class of 3 (being the lowest tolerance class encountered in the sample) would be assigned a BBI of 5. The column with indicator groups in Table 2 contains some modifications, which will be discussed further in this paper. BBI values correspond to water quality classes with their associated formal valuation, which are summarised in Table 3 (De Pauw & Vanhooren, 1983).

Bervoets et al. (1989) proposed, along with some modifications in sample processing, to

Table 1. Identification levels of macroinvertebrate taxa for calculating the BBI (De Pauw & Vanhooren, 1983)

Taxonomic group	Determination level of systematic units
Plathelminthes	Genus
Oligochaeta	Family
Hirudinea	Genus
Mollusca	Genus
Crustacea	Family
Plecoptera	Genus
Ephemeroptera	Genus
Trichoptera	Family
Odonata	Genus
Megaloptera	Genus
Hemiptera	Genus
Coleoptera	Family
Diptera	Family, excl. Chironomidae (Chironomidae *thummi-plumosus*, Chironomidae *non-thummi-plumosus*)
Hydracarina	Presence

include taxa represented by only one individual in BBI calculation, but this modification was never incorporated into routinely monitoring schemes of the VMM.

Table 3. Water quality classes corresponding to the BBI values (De Pauw & Vanhooren, 1983)

Quality class	BBI	Colour code	Valuation
I	9–10	Blue	Lightly polluted or unpolluted
II	7–8	Green	Slightly polluted
III	5–6	Yellow	Moderately polluted
IV	3–4	Orange	Heavily polluted
V	0–2	Red	Very heavily polluted

Inconsistencies due to taxonomic modifications

De Pauw & Vannevel (1991) published keys in Dutch for identification of aquatic macroinvertebrates, for each group up to the appropriate BBI level. Since the publication of these identification keys, taxonomy of some groups of macroinvertebrates was changed, resulting in genera splitting up into more than one genus. Examples are the gastropod genera *Lymnaea*, *Stagnicola*, *Radix* and *Galba*, formerly all considered as *Lymnaea* species; the gastropod *Physella*, formerly belonging to the genus *Physa*; and *Aquarius najas* (De Geer, 1773), formerly belonging to the genus *Gerris*. As a result,

Table 2. Calculation of the BBI, based on the highest tolerance class encountered, the class frequency within the highest tolerance class and the total number of taxa (De Pauw & Vanhooren, 1983)

Tolerance class Indicator groups	Class Frequency	Number of taxa				
		0–1	2–5	6–10	11–15	≥16
1. Plecoptera; Heptageniidae	≥2	–	7	8	9	10
	1	5	6	7	8	9
2. Cased Trichoptera	≥2	–	6	7	8	9
	1	5	5	6	7	8
3. Ancylidae; *Acroloxus*; Ephemeroptera (excl. Heptageniidae)	> 2	–	5	6	7	8
	1–2	3	4	5	6	7
4. *Aphelocheirus*; Odonata; Gammaridae; Mollusca (excl. **Ancylidae**, *Acroloxus*, Sphaeriidae & *Corbicula*)	≥1	3	4	5	6	7
5. Asellidae; Hirudinea; Sphaeriidae; Hemiptera (excl. *Aphelocheirus*)	≥1	2	3	4	5	–
6 .Tubificidae Chironomidae *thummi-plumosus*	≥1	1	2	3	–	–
7. Syrphidae-Eristalinae	≥1	0	1	1	–	–

Proposed modifications of indicator groups after Gabriels et al., this paper (in bold).

two samples containing the same species and the same number of individuals for each species could result in a different index depending on whether the current state-of-the-art in taxonomy is followed for identifying the organisms or the taxonomic levels *sensu* De Pauw & Vannevel (1991) are used.

This is demonstrated with a simple example of a BBI calculation for two virtual samples (Table 4). The two approaches produce different BBI values in both examples. Table 4 (panels A and B) gives a list of species with their respective abundances and tolerance classes. Subsequently, the BBI is calculated following both approaches. In the first example (Table 4, panel A), identification of the sample following the keys of De Pauw & Vannevel (1991) will result in a decrease of taxa richness with two units, and a decrease of the BBI with one unit, because the genera *Aquarius* and *Radix* are assigned to other genera (*Gerris* and *Lymnaea*, respectively). In the second example (Table 4, panel B) the actual taxa richness decreases with one unit, but for BBI calculation it increases with a unit because two individuals are only counted when representing the same taxon since two is the minimal abundance for inclusion in BBI calculation. As a result, the BBI increases with two units in this case.

Both approaches can be justified since the original publication of the BBI (De Pauw & Vanhooren, 1983) only indicates the levels of identification (Table 1). Application of the BBI *sensu stricto* today would therefore imply using the current levels of identification, although only using the same taxonomic identification keys at all time would lead to stable results, i.e. a time-independent calculation of BBI values.

An estimation of the percentage of actual samples for which both approaches provide different results was not possible since the identifications of the VMM are only recorded at the lumped levels (e.g. *Lymnaea* including *Stagnicola*, *Radix* and *Galba*). In order to obtain a rough indication, both approaches were compared for *Anisus*, a genus that was split before the publication of the identification keys of De Pauw & Vannevel (1991) and hence all actual taxa are recorded in the VMM data set. The recorded taxa are *Anisus*, *Armiger*, *Bathyomphalus*, *Gyraulus*, *Hippeutis*, *Planorbis* and *Segmentina*. Two hundred and eighty four samples from the VMM data set contained at least two individuals of at least two of the seven taxa. BBI was calculated for these samples when distinguishing the seven taxa and calculated again after summing the abundances of the seven taxa into one taxon, *Anisus*. For 34 samples (12.0%), summing the taxa resulted in a BBI decrease of one unit. The other samples were not affected.

Since there is no reason to assume that taxonomic modifications will not proceed in future, this problem can only be overcome by using a fixed list of taxa at all time (or, more correctly, a semi-fixed list; see further). The establishment of a common list of taxa was already recommended by Woodiwiss (1980). For the German saprobic index, a fixed taxon list is already in use (DIN, 1990).

Inconsistencies due to the introduction of exotic species

Adverse effects of invasive species on ecosystems have been discussed by several authors (e.g. Lodge, 1993; Cairns & Bidwell, 1996; Mack et al., 2000; Torchin et al., 2003). Invasion of exotic macroinvertebrate genera in Europe is increasing (e.g. Van den Brink et al., 1991; Bij de Vaate et al., 2002). These invasions cause controversy on the subject of index-based biological assessment, strongly related to the question whether or not a fixed taxa list is used. An important aspect of this controversy is the higher potential number of taxa present in monitoring samples due to these introductions, which may cause an increase in index number when using an index dependent on taxa richness. Though alpha diversity, expressed as number of taxa, may have risen, this will only be reflected in index calculation provided the new taxon is included in the list for index calculation. On the other hand, introduction of exotic species might as well cause a decrease of alpha diversity, which is masked due to a higher taxonomic identification level. For example, the invader *Dikerogammarus villosus* (Sowinsky, 1894) (Crustacea, Gammaridae) might outcompete a number of native gammarid species (e.g. Bij de Vaate et al., 2002), but this will not influence the results of the index calculation at family level of a given sample since Gammaridae are still present.

Table 4. Calculation of the BBI of two virtual samples

Species	Abundance	Tolerance class	Taxa according to the current state-of-the-art taxonomy (each at the applicable level)	Taxa according to the taxonomy as applied in De Pauw & Vannevel (1991) (each at the applicable level)
Panel A. Example resulting in a decreased BBI due to taxonomic changes				
Tubifex tubifex	100	6	Tubificidae	Tubificidae
Chironomus riparius	45	–	Chironomidae *non-thummi-plumosus*	Chironomidae *non-thummi-plumosus*
Erpobdella octoculata	4	–	*Erpobdella*	*Erpobdella*
Lymnaea stagnalis	5	4	*Lymnaea*	*Lymnaea*
Radix peregra	2	4	*Radix*	
Gerris lacustris	4	5	*Gerris*	*Gerris*
Aquarius najas	2	5	*Aquarius*	
Total number of taxa			7	5
Lowest tolerance class			4	4
Tolerance class frequency			2	1
BBI			5	4
Water quality class			III (yellow)	IV (orange)
Panel B. Example resulting in an increased BBI due to taxonomic changes				
Tubifex tubifex	100	6	Tubificidae	Tubificidae
Chironomus riparius	45	–	Chironomidae *non-thummi-plumosus*	Chironomidae *non-thummi-plumosus*
Erpobdella octoculata	4	–	*Erpobdella*	*Erpobdella*
Lymnaea stagnalis	1	4	(*Lymnaea*)	*Lymnaea*
Radix peregra	1	4	(*Radix*)	
Gerris lacustris	2	5	*Gerris*	*Gerris*
Sialis lutaria	10	–	*Sialis*	*Sialis*
Total number of taxa			5	6
Lowest tolerance class			5	4
Tolerance class frequency			1	2
BBI			3	5
Water quality class			IV (orange)	III (yellow)

The first and second column of both panels A and B list the species and their respective abundances, the third one the tolerance classes, the fourth one the taxa according to the current state-of-the-art taxonomy (each at the applicable level), and the fifth one the taxa according to the taxonomy as applied in De Pauw & Vannevel (1991) (each at the applicable level). At the bottom of the fourth and fifth column the BBI and the respective water quality class is indicated for both approaches.

Nguyen & De Pauw (2002) reported the invasion of the Asian clams *Corbicula fluminea* (Müller, 1774) and *Corbicula fluminalis* (Müller, 1774) (Mollusca, Corbiculidae) in the Belgian section of the river Meuse, and some of the connected canals in the early 1990s and the continuing colonisation of *Corbicula* species in Belgian watercourses. They could not establish a correlation between the clam density or proportion and the quality of the sediment. Since no tolerance class is defined for *Corbicula*, this may cause inconsistencies in BBI calculations due to a lack of consensus on how to deal with this phenomenon. The VMM encounters this genus more and more frequently in its biological samples. The question emerged whether or not this exotic genus should be included in BBI calculation, and if so, which tolerance class to use. A strict interpretation of the tolerance class as described by De Pauw & Vanhooren (1983) would lead to the inclusion of *Corbicula* in the standard list with a tolerance class of 4, being a non-sphaeriid mollusc, and thus being quite tolerant. By means of two calculation examples it is demonstrated that this may cause differences in index calculation (Table 5).

Table 5 (panels A and B) gives a list of taxa with their respective abundances. Then the BBI is calculated according to three different approaches. In the first approach, *Corbicula* is neglected, in the second it is included without tolerance class ('–') and in the third it is included with a tolerance class of 4. Note the difference between a tolerance class '–' and the absence of a tolerance class. With a '–' tolerance the taxon is only taken into account for taxon richness, while in the absence of a tolerance class the taxon is not included at all. The first example (Table 5, panel A) is a sample actually taken by the VMM on 6 May 1998 at a sampling site in the Albert Canal at Genk. In this case, the inclusion of *Corbicula* leads to an increase of the BBI from 6 to 7. The VMM reported the BBI of this sampling site as 7, and consequently this site met the basic water quality conditions (BBI = 7) thanks to *Corbicula*. In the second example (Table 5, panel B), a virtual sample, it is demonstrated that the three approaches can as well lead to three different BBI values.

Eighteen samples from the data set of the VMM contained *Corbicula* individuals. In twelve of these samples, at least two individuals were counted and hence *Corbicula* was included in the BBI calculation of these samples. For one sample (Table 5, panel A), the BBI was affected when *Corbicula* was discarded. The number of samples was however statistically insufficient and therefore conclusions on the probability of affecting the BBI could not yet be drawn. Nguyen & De Pauw (2002) found that including *Corbicula* species in the Biotic Sediment Index (BSI; De Pauw & Heylen, 2001), altered biological sediment quality classification in 52% of the cases.

In order to obtain a more reliable indication of the frequency of BBI alteration if an alien taxon would be discarded, the same calculation was performed for *Dreissena*, another alien bivalve that was already included in the taxa list of De Pauw & Vannevel (1991), with a tolerance class of 4. *Dreissena* is already present in Belgian waters for a longer time and consequently more data were available for comparing calculations. Four hundred and twenty one samples from the VMM data set contained at least two *Dreissena* individuals. The BBI was calculated for all samples and recalculated after exclusion of *Dreissena*. For 100 samples (23.8%), BBI values decreased when *Dreissena* was excluded. Ninety eight of these (23.3%) decreased with one BBI unit and two (0.5%) with two units.

Biodiversity loss that is not evident at the taxonomic level of the biotic index used, is a matter of bioconservation and not of biological assessment of water quality. Therefore the new genus should be included in the taxa list since it has become part of local biodiversity. A biotic index, *in casu* the BBI, is partly based on a rapid biodiversity survey (expressed as number of taxa) as an indicator of the water quality, not of the ecosystem stability. Furthermore, species that invaded our regions at earlier times were already included in water quality assessment and are nowadays commonly accepted. Therefore, it is recommended to include *Corbicula* in the standard taxa list, despite its potential harmful effects. To obtain insight in the adverse effects of the invasion of this genus, more detailed studies – at species level – are necessary.

The VMM has already added the genus *Corbicula* to its standard list for calculating the BBI, however without assigning a specific tolerance class to it ('–'). In this way, *Corbicula* only affects the BBI through the number of taxa and not

Table 5. Calculation of the BBI of a real (panel A) and a virtual (panel B) sample

Taxa	Abundance	Tolerance class without inclusion of *Corbicula*	Tolerance class if *Corbicula* is included without tolerance class	Tolerance class according to De Pauw & Vanhooren (1983) *sensu stricto*
Panel A. Sample taken by the VMM on 6 May 1998 at sampling site no. VMM-820000 in the Albert Canal at Genk				
Naididae	2	–	–	–
Tubificidae	11	6	6	6
Chironomidae *non-thummi-plumosus*	11	–	–	–
Helobdella	1			
Erpobdella	11	5	5	5
Gammaridae	11	4	4	4
Atyidae	11	–	–	–
Asellidae	1	–	–	–
Cambaridae	2	–	–	–
Bithynia	11	4	4	4
Ancylus	2	3	3	3
Dreissena	11	4	4	4
Sphaerium	11	5	5	5
Corbicula	2		–	4
Valvata	2	4	4	4
Physa	2	4	4	4
Pisidium	2	5	5	5
Ecnomidae	11	–	–	–
Total number of taxa		15	16	16
Lowest tolerance class		3	3	3
Tolerance class frequency		1	1	1
BBI		6	7	7
Water quality class		III (yellow)	II (green)	II (green)
Panel B. Virtual sample				
Tubificidae	100	6	6	6
Chironomidae *thummi-plumosus*	45	6	6	6
Asellidae	20	5	5	5
Erpobdella	4	5	5	5
Gerris	2	5	5	5
Corbicula	50		–	4
Total number of taxa		5	6	6
Lowest tolerance class		5	5	4
Tolerance class frequency		3	3	1
BBI		3	4	5
Water quality class		IV (orange)	IV (orange)	III (yellow)

The first column lists the taxa, the second one the abundances, the third one the tolerance classes if *Corbicula* is not included, the fourth one the tolerance classes if *Corbicula* is included without tolerance class (‘–’), and the fifth one the tolerance classes according to De Pauw & Vanhooren (1983) *sensu stricto*.

through its tolerance class, which is also the case for e.g. the taxa of Plathelminthes and most Diptera.

A number of exotic species of Ponto-Caspian origin are invading European watercourses (e.g. Bij de Vaate et al., 2002). Many of these species such as *Dikerogammarus villosus*, belong to a taxon *(in casu* Gammaridae) that is already in the list, while others will have to be included in the list as new taxa, for the same reasons as *Corbicula*. Some of these are very likely to be encountered in Flemish watercourses in the near future. Anticipating this, two Ponto-Caspian taxa should already be added to the list: Ampharetidae (Polychaeta) and Janiridae (Crustacea).

The presence of *Hypania invalida* (Grube, 1860) (Polychaeta, Ampharetidae) was recently reported in the river Meuse (Vanden Bossche et al., 2001). Although not yet encountered in VMM samples, this may be expected in the near future, especially in the Flemish stretch of the river Meuse. Therefore, Polychaeta should be added as a new group, including one taxon, Ampharetidae, with tolerance class '–', the identification level being set at family (as for Oligochaeta). Another Ponto-Caspian invader, *Jaera istri* (Veuille, 1979) (Crustacea, Janiridae) has also recently been encountered in the river Meuse (Usseglio-Polatera & Beisel, 2003), although not collected in VMM samples so far. Consequently, the list of Crustacea should be extended with the family Janiridae, with tolerance class '–'.

List of taxa taken into consideration

There is indeed a growing need to ensure that the BBI-values remain comparable in future, which implies not altering the method itself, but rather clarifying the problems that emerge, to ensure its future application without being inconsistent with the past and current practice. Altering the method itself would imply making old and new applications incomparable; in other words, it would be a different index. The aim of this paper with regard to the BBI was to identify the problems that arose since 1991 and propose solutions to these problems.

Initially, a checklist by Vanhooren et al. (1982) was commonly used as a reference base for taxonomy of the systematic levels used in the BBI calculation. Some additional taxa were added later, e.g. due to the separation of the mollusc genus *Anisus* into *Anisus*, *Armiger*, *Bathyomphalus*, *Gyraulus*, *Hippeutis*, *Planorbis* and *Segmentina*.

Although the original description of the BBI method dates from 1983, the situation in 1991 was chosen as point of reference. At that moment, the aforementioned modifications were already established and commonly accepted. The situation in 1991 was chosen as point of reference for two reasons. The first reason is that at that time a large-scale monitoring network in Flanders was being initiated by the VMM, with the already cited modifications. The second reason is that the keys of the Pauw & Vannevel (1991) are nowadays widely used and accepted as standard reference for taxonomic identification levels with regard to the BBI.

In the previous paragraphs it has been shown that taxonomic modifications and alien invasions may both lead to biased BBI calculations. Although a change of one or two units in BBI (on a 0–10 scale) may seem insignificant, it is not. A small change in BBI may also lead to a change in the quality class (cf. Table 3). This may become (legally) crucial when this quality class boundary is also a quality standard, e.g. the boundary between the ecological quality classes 'good' and 'moderate', the target imposed by the European Water Framework Directive (EU, 2000). Moreover, a standardised assessment method should be unambiguously applicable and produce unbiased results at all times. This underpins the need for establishing a fixed taxa list. Because more exotic taxa can be expected to invade Belgian watercourses in the future, a fixed taxa list may need to be extended later with those taxa. Therefore a proposal for a fixed taxa list should be more likely called a semi-fixed list, leaving the possibility to add new taxa at a later time.

Table 6 is a proposal for a semi-fixed list to be used to calculate the BBI in order to eliminate the discussed calculation inconsistencies. This list contains 221 taxa and can be considered as a semi-fixed list, in the sense that the taxa already in the list cannot be altered (e.g. split up or lumped), but that the list may be extended with possible future invaders when necessary. The list is based on the taxa identification *sensu* De Pauw & Vannevel (1991) with the addition of the Polychaeta family

Table 6. Proposed semi-fixed taxa list of aquatic macroinvertebrates for calculating the BBI in order to avoid inconsistencies

Taxon	Tolerance class
Plathelmintes	
Bdellocephala	–
Crenobia	–
Dendrocoelum	–
Dugesia	–
Phagocata	–
Planaria	–
Polycelis	–
Polychaeta	
Ampharetidae	–
Oligochaeta	
Aelosomatidae	–
Branchiobdellidae	–
Enchytraeidae	–
Haplotaxidae	–
Lumbricidae	–
Lumbriculidae	–
Naididae	–
Tubificidae	6
Hirudinea	
Cystobranchus	5
Dina	5
Erpobdella	5
Glossiphonia	5
Haementeria	5
Haemopis	5
Helobdella	5
Hemiclepsis	5
Hirudo	5
Piscicola	5
Theromyzon	5
Trocheta	5
Mollusca	
Acroloxus	3
Ancylus	3
Anisus	4
Anodonta	4
Aplexa	4
Armiger	4
Bathyomphalus	4
Bithynia	4
Bythinella	4
Corbicula	–

Table 6. (Continued)

Taxon	Tolerance class
Dreissena	4
Ferrissia	3
Gyraulus	4
Hippeutis	4
Lithoglyphus	4
Lymnaea s.l.	4
Margaritifera	4
Marstoniopsis	4
Myxas	4
Physa s.l.	4
Pisidium	5
Planorbarius	4
Planorbis	4
Potamopyrgus	4
Pseudamnicola s.l.	4
Pseudanodonta	4
Segmentina	4
Sphaerium	5
Theodoxus	4
Unio	4
Valvata	4
Viviparus	4
Acari	
Hydracarina s.l.	–
Crustacea	
Argulidae	–
Asellidae	5
Astacidae	–
Atyidae	–
Cambaridae	–
Chirocephalidae	–
Corophiidae	–
Crangonyctidae	–
Gammaridae	4
Grapsidae	–
Janiridae	–
Leptestheriidae	–
Limnadiidae	–
Mysidae	–
Palaemonidae	–
Talitridae	–
Triopsidae	–
Ephemeroptera	
Baetis	3

Continued on p. 146

Table 6. (Continued)

Taxon	Tolerance class
Brachycercus	3
Caenis	3
Centroptilum	3
Cloeon	3
Ecdyonurus	1
Epeorus	1
Ephemera	3
Ephemerella	3
Ephoron	3
Habroleptoides	3
Habrophlebia	3
Heptagenia	1
Isonychia	3
Leptophlebia	3
Metreletus	3
Oligoneuriella	3
Paraleptophlebia	3.
Potamanthus	3
Procloeon	3
Rhitrogena	1
Siphlonurus	3
Odonata	
Aeshna	4
Anax	4
Brachytron	4
Calopteryx	4
Cercion	4
Ceriagrion	4
Coenagrion	4
Cordulegaster	4
Cordulia	4
Crocothemis	4
Enallagma	4
Epitheca	4
Erythromma	4
Gomphus	4
Ischnura	4
Lestes	4
Leucorrhinia	4
Libellula	4
Nehalennia	4
Onychogomphus	4
Ophiogomphus	4
Orthetrum	4
Oxygastra	4
Platycnemis	4

Table 6. (Continued)

Taxon	Tolerance class
Pyrrhosoma	4
Somatochlora	4
Sympecma	4
Sympetrum	4
Plecoptera	
Amphinemura	1
Brachyptera	1
Capnia	1
Chloroperla	1
Dinocras	1
Isogenus	1
Isoperla	1
Leuctra	1
Marthamea	1
Nemoura	1
Nemurella	1
Perla	1
Perlodes	1
Protonemura	1
Rhabdiopteryx	1
Taeniopteryx	1
Hemiptera	
Aphelocheirus	4
Arctocorisa	5
Callicorixa	5
Corixa	5
Cymatia	5
Gerris s.l.	5
Glaenocorisa	5
Hebrus	5
Hesperocorixa	5
Hydrometra	5
Llyocoris	5
Mesovelia	5
Micronecta	5
Microvelia	5
Naucoris	5
Nepa	5
Notonecta	5
Paracorixa	5
Plea	5
Ranatra	5
Sigara	5
Velia	5

Continued on p. 147

Table 6. (Continued)

Taxon	Tolerance class
Megaloptera	
Sialis	–
Coleoptera	
Dryopidae	–
Dytiscidae	–
Elminthidae	–
Gyrinidae	–
Haliplidae	–
Hydraenidae	–
Hydrophilidae	–
Hygrobiidae	–
Noteridae	–
Psephenidae	–
Scirtidae	–
Trichoptera	
Beraeidae	2
Brachycentridae	2
Ecnomidae	–
Glossosomatidae	2
Goeridae	2
Hydropsychidae	–
Hydroptilidae	2
Lepidostomatidae	2
Leptoceridae	2
Limnephilidae	2
Molannidae	2
Odontoceridae	2
Philopotamidae	–
Phryganeidae	2
Polycentropodidae	–
Psychomyidae	–
Rhyacophilidae	–
Sericostomatidae	2
Diptera	
Athericidae	–
Blephariceridae	–
Ceratopogonidae	–
Chaoboridae	–
Chironomidae *non-thummi-plumosus*	–
Chironomidae *thummi-plumosus*	6
Culicidae	–
Cylindrotomidae	–
Dixidae	–
Dolichopodidae	–

Table 6. (Continued)

Taxon	Tolerance class
Empididae	–
Ephydridae	–
Limoniidae	–
Muscidae	–
Psychodidae	–
Ptychopteridae	–
Rhagionidae	–
Scatophagidae	–
Sciomyzidae	–
Simuliidae	–
Stratiomyidae	–
Syrphidae-Eristalinae	7
Tabanidae	–
Thaumaleidae	–
Tipulidae	–

The first column lists the taxa, the second one the associated tolerance classes. *Lymnaea* s.l. = *Lymnaea* or *Stagnicola* or *Radix* or *Galba* ; *Physa* s.l. = *Physa* or *Physella*; *Pseudamnicola* s.l. = *Pseudamnicola* or *Mercuria* ; Hydracarina s.l. = Hydracarina or *Hydrozetes*; *Gerris* s.l. = *Gerris* or *Aquarius*.

Ampharetidae, the Mollusca genus *Corbicula* and the Crustacea family Janiridae. The notation 's.l.' (*sensu lato*) was added to those taxa that comprise one or more taxa in addition to the one actually mentioned. In the case of Hydracarina the notation s.l. already appeared on the original list of De Pauw & Vannevel (1991) because Hydracarina s.l. comprises *Hydrozetes* in addition to Hydracarina s.s. (*sensu stricto*). Because the Belgian Insitute of Normalisation has adopted the BBI as a standard method (IBN, 1984), it is recommended that its method description (NBN T92-402) be extended by including this new semi-fixed taxa list.

Taxa belonging to groups such as Bryozoa, Hydrozoa, Nemertea, Nematoda, Ostracoda and Porifera are not included in the new taxa list. Taxa from these groups are not frequently encountered in macroinvertebrate samples. These groups already did not appear on the original list in De Pauw & Vannevel (1991), and their addition would cause new inconsistencies between BBI calculations, since they may have been present in older samples. This problem does not arise with new, exotic taxa since they were not yet encountered in the older samples. For this reason, the mentioned groups of taxa were not added to the list.

Comparison of the tolerance classes of Table 6 with the indicator groups from Table 2 reveals some inconsistencies as well. *Acroloxus*, having a tolerance class 3, is not included in the appropriate column in Table 2. This is due to the fact that according to Vanhooren et al. (1982), *Acroloxus* belonged to the family Ancylidae, which is included in Table 2 among tolerance class 3. Since *Acroloxus* is now considered as belonging to a separate family (Acroloxidae), it should be included there as well. Furthermore, not only Sphaeriidae should be excluded from the Mollusca mentioned in tolerance class 4, but also *Corbicula*, Ancylidae and *Acroloxus*. All mentioned inconsistencies were corrected and indicated in bold in Table 2.

The proposal for future application of the BBI is therefore as follows:

(1) application of the taxa list from Table 6 with the associated tolerance classes;
(2) calculation of the index value based on all taxa of which more than one individual was found, using Table 2;
(3) determination of water quality class by means of Table 3.

Sampling macroinvertebrates and calculating the BBI is a rigorous task and should be performed with the highest possible care and precision. Along with the calculation method, many other sources of variability exist, such as seasonality (e.g. Hughes, 1978; Furse et al., 1984; Rosillon, 1989; Linke et al., 1999; Humphrey et al., 2000; Reece et al., 2001), operator (e.g. Humphrey et al., 2000) and sampling variation (e.g. Clarke, 2000; Clarke et al., 2002). Due to all these sources of variability, it is difficult to attain a high precision for the BBI. Nevertheless, these other sources of errors are an additional incentive for using a calculation method that is as rigorous as possible.

Conclusion

Lack of consensus on how to deal with taxonomic modifications and invasions of exotic species may lead to inconsistencies in biotic index calculation. This problem could be overcome by using a semi-fixed taxa list. A semi-fixed list of macroinvertebrate taxa including a tolerance class for each taxon is proposed in order to avoid inconsistencies in the calculation procedure of the BBI. This list is based on the taxa identification *sensu* De Pauw & Vannevel (1991) with the addition of the Polychaeta family Ampharetidae, the Mollusca genus *Corbicula* and the Crustacea family Janiridae. It is hoped for that this list may lead to a harmonisation of the BBI calculation practice so that the BBI values can still be compared unambiguously in the future.

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