Verh. Internat. Verein. Limnol.	27	1822–1830	Stuttgart, December 2000

Biological assessment of running waters in Denmark: introduction of the Danish Stream Fauna Index (DSFI)

Jens Skriver, Nikolai Friberg and Jørn Kirkegaard

Introduction

Biological assessment of running waters is an old discipline (KOLKWITZ & MARSSON 1902), where different taxonomic groups i.e. diatoms, macrophytes, macroinvertebrates and fish have been used for many years. Macroinvertebrates are currently the most widely used organisms (METCALFE 1989, DE PAUW et al. 1992), their main attributes being that it is possible to select a gradient between sensitive, indifferent and tolerant forms.

Other important factors are that macroinvertebrates are present throughout the year, are relatively sessile, and relatively easy to collect and identify (DE PAUW & HAWKES 1993). Over the last two decades, many European countries have developed biotic indices for biomonitoring at the local, regional or national levels (e.g. ARMITAGE et al. 1983, DE PAUW & VANHOOREN 1983, FRIEDRICH 1990, AFNOR NFT 90–350 1992, GHETTI 1997, ALBA-TERCEDOR & PUJANTE 2000).

Routine biological assessment of running waters has been performed in Denmark since the beginning of the 1970s, but was at that time based on a rather subjective method (MINISTRY OF AGRICULTURE 1970). Work on development of a biotic index for use in Denmark started about 1980, and the first version was presented by ANDERSEN et al. (1984). A third version of a Danish biotic index, the Danish Stream Fauna Index (DSFI), has now been introduced as the national standard biomonitoring method (DANISH ENVIRONMENTAL PROTECTION AGENCY 1998).

The aim of this paper is to provide an overview of biological assessment of running waters in Denmark and present the new biomonitoring method.

Biological assessment of running waters in Denmark during the period 1970–1998

Legislation and quality objectives

Earlier this century, most Danish streams became severely physically modified because of stream regulation. At the same time Danish streams became increasingly polluted, consequently numerous sewage treatment plants were constructed in the 1950s and 1960s to combat this pollution. Endeavours to combat water pollution intensified with the introduction of the Environmental Protection Act in 1974. The Act, among other things, stipulates a planning system requiring specific quality objectives to be set for individual streams. These quality objectives are set and controlled by the regional authorities (counties). The quality objectives are in most cases fulfilled if the macroinvertebrate community is unimpacted or only slightly impacted, corresponding to pollution degree I, I–II or II (see next section). In the 1980s and 1990s it has become much more apparent that besides organic pollution the in-stream physical conditions also play an important role for the macroinvertebrate community and the fulfilment of the quality objectives (SKRIVER et al. 1997, OLSEN & FRIBERG 1999). In cases where the quality objectives are not fulfilled the regional authority has to identify the cause and implement any necessary additional treatment of sewage effluent, or alternatively improve the physical conditions of the stream if these are believed to be the main reason for unacceptable ecological quality.

Ministry of Agriculture: Guidelines on stream biomonitoring

The first biomonitoring method used as a national standard dates back to 1970, when guidelines were published by the Danish Ministry of Agriculture (MINISTRY OF AGRICULTURE 1970). Benthic macroinvertebrates were collected by means of a handnet with a 1 mm

0368-0770/00/0027-01822 $ 2.25

mesh size. Macroinvertebrates were identified in the field to the highest possible level, which in most cases was genus, family or order. The outcome of the assessment was therefore very dependent on the taxonomic skills and experience of the person undertaking the field sampling. The method used seven pollution degrees denoted by Roman numerals ranging from I to IV including the intermediate steps (I–II, etc.). The four main pollution degrees (I, II, III and IV) were denoted unpolluted, slightly polluted, strongly polluted and very strongly polluted. How a given macroinvertebrate species composition was to be interpreted in terms of pollution degree was only very roughly described in the guidelines and the assessments were therefore very subjective. This resulted in different practices throughout the country because each of the regional authorities developed their own interpretation of the original method. Despite the limitations and subjective character of the assessment system it was the official Danish biomonitoring method until 1998. This has complicated both inter-regional and temporal comparisons.

Viborg Index

To overcome the shortcomings of the official biomonitoring method from 1970, a research project was initiated at the Freshwater Laboratory of the University of Copenhagen in the late 1970s whereby three M.Sc. students developed a biotic index based on the principles used in the Trent Biotic Index (Woodiwiss 1964). Two experienced biologists were used as a reference in interpreting 149 fauna lists using the official biomonitoring method. The students then developed a Danish biotic index having the best fit to the results of the official method. This new biotic index also used seven index values denoted by Roman numerals like the official method from 1970. The index has been used in Denmark under the name Viborg Index because most of the samples on which the index was based were collected in the county of Viborg (Andersen et al. 1984).

Like the official biomonitoring method described in the document of the Ministry of Agriculture (1970), the Viborg Index was originally developed to assess organic pollution with the index values being termed pollution degrees. It has subsequently been shown, however, that the Viborg Index is also sensitive to other forms of anthropogenic impact. The Viborg Index has never been a national standard in Denmark, but was used by some Danish counties up to 1992.

Danish Fauna Index (DFI)

A working group appointed by the Danish Environmental Protection Agency used the Viborg Index as a template for a new official Danish biotic index, testing the index to see whether it could be applied in regions throughout Denmark characterised by different topographies. On the basis of this test and the comments of experienced county biologists, the working group decided to make a few changes to the Viborg Index. Firstly, a new indicator group was incorporated to improve the index at the lower end of the scale. Secondly, a minor change was made to the number of caddis larvae (other Trichoptera). This revised index was named the Danish Fauna Index (DFI) and still used Roman numerals as in the Viborg Index. As the DFI was believed to give an overall description of all anthropogenic impacts, the term pollution degree was changed to fauna class. The DFI has never been used officially as the standard method, but was used during the period 1993–97 for biological assessment of the approx. 220 sites included in the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment (Kirkegaard et al. 1992).

In 1996, a new working group was established with participants from the National Environmental Research Institute (NERI), the Danish Environmental Protection Agency and the Danish counties. The motive for this new working group was that county biologists argued that the DFI had more disadvantages than benefits. Therefore, the counties made proposals for some changes in the DFI. Most of the proposals were either the introduction of new indicator taxa or the elimination of taxa already used as indicators. On the basis of the proposals, the working group decided to make

four alternative modifications of the DFI. Two hundred fauna lists were then used to test the DFI together with these four modifications. As a reference, the two biologists involved in development of the Viborg Index interpreted the fauna lists using the official biomonitoring method from 1970. One of the four modifications was found to fit the reference list slightly better than the DFI. The material was further analysed, and it was found that a small change in the calculation of the index value used in the DFI was sufficient to improve the fit. The working group recommended this change in the new index as well as a revision of the scale and the use of Arabic numerals 1 to 7 instead of Roman numerals (FRIBERG et al. 1996). The use of Arabic numerals better enabled the new Danish Stream Fauna Index (DSFI) to be compared to other European biotic indices, where the highest number represents the best ecological quality.

Danish Stream Fauna Index (DSFI)

The Danish Stream Fauna Index (in Danish – Dansk Vandløbs Fauna Indeks, DVFI) is a standardised method, which replaces the old subjective method from 1970. The DSFI was introduced as the official method for biological assessment of running waters in Denmark from 1998 (DANISH ENVIRONMENTAL PROTECTION AGENCY 1998).

In the following, is given a description of the sampling and sorting procedure, the necessary identification level, demand for enumeration and finally the calculation of the DSFI index value.

Sampling

The sampling procedure is standardised, and includes, in principle, sampling of all microhabitats at the site. Sampling is undertaken using a standard handnet with a 25 × 25 cm opening and a tapering netbag with a mesh size of 0.5 mm. Sampling is done at three transects across the stream lying about 10 m apart, four kick samples are taken at each transect 25%, 50%, 75% and 100% from one of the stream banks (Fig. 1). If stream width is less than 1 m, i.e. the width of four handnet heads, the transects should be placed diagonally in an upstream direction. Sampling is started at the downstream transect and progresses upstream. The 12 kick samples are pooled for further analysis. The kick samples are collected by placing the handnet on the stream bed, and then placing a foot on the stream bed in front of the handnet, with the toes pointing downstream. The foot is then moved backwards about 40 cm against the current, and animals and sediment are swept by the current into the net. Once the sediment has settled, the procedure is repeated at the same spot, without having moved the net. At low current velocities, however, a slightly different sampling approach has to be used. After kicking into the bottom substrate with the foot it is necessary to move the handnet actively in the upstream direction to compensate for the low current velocity.

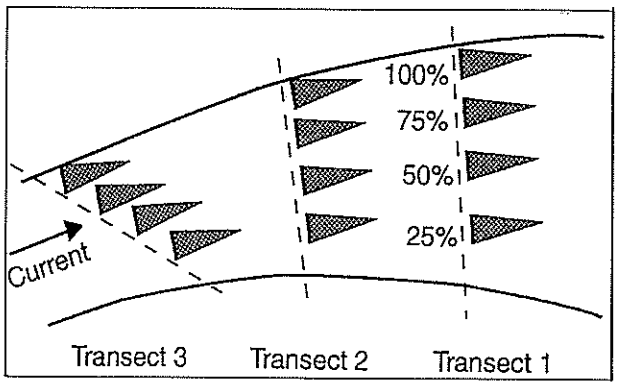

Fig. 1. Kick sampling in three transects across the stream. As a supplement, hand-picking is performed on stones and large wooden debris. These two sample types are kept separate during identification, counting and calculation of the index value.

In deep rivers, the standard method of sampling may be impossible because sampling is performed along transects. In this case it is recommended to sample all available substrate types present along the bank.

Since many animals such as . flatworms, leeches, snails and caddis larvae, with stone cases, adhere firmly to the substrate and tend to be under-represented, kick sampling is supplemented by 5 min of hand-picking from submerged stones and large wooden debris. The animals collected by hand-picking are kept separately from the kick sample.

The pooled kick sample and the hand-picked sample, which together constitute the fauna sample, are preserved separately in the field and are subsequently analysed in the laboratory. If necessary the kick sample is sieved in the field or in the laboratory in a sieve with mesh size 0.5 mm.

Sorting, identification and counting

The macroinvertebrates are sorted and identified in the laboratory. Further sorting and identification is generally not necessary when two specimens of a taxon have been identified in the kick sample or one specimen in the hand-picked sample. Some taxa have to be found in higher numbers i.e. *Gammarus*, "other Trichoptera", Simuliidae, Oligochaeta, *Asellus* and *Chironomus* (see below for further explanation). The macroinvertebrates have to be identified at least to the taxonomic level indicated in Table 1.

Calculation of the index value

The Danish Stream Fauna Index is presented in Table 2. The index value (fauna class) is determined on the basis of indicator taxa and the number of diversity groups in the total fauna sample (kick samples + hand-picked samples). In this way, ecological quality in running waters is described by index values ranging from 1 to 7, with the highest number representing the best ecological quality.

The DSFI comprises six indicator groups (IGs) – (see Table 2), each having a number of taxonomic groups as entrance points. A taxon used in an indicator group is said to be present if at least two specimens are found in the kick sample, or if at least one specimen is found in the hand-picked sample. There are, however, some exceptions for the kick sample. In IG 3, for example, other Trichoptera have to number ≥5 specimens, and *Gammarus* can only be used as an indicator in IG 3 and IG 4 if there are ≥10 specimens. In IG 5, *Gammarus* can be used if there are 2–9 specimens, and Simuliidae have to number ≥25 specimens if this taxon is to be used as an entrance point here.

The number of diversity groups is calculated from the number of positive diversity groups minus the number of negative diversity groups (Table 3). Only selected taxa are used as diversity groups. Accordingly, rather common taxa like Hydracarina, Corixidae, Bivalvia as well as most Coleopterans, Dipterans and Gastropoda are not considered. Four ranges of diversity groups are used in the DSFI (Table 2). It should be noted that the presence in the fauna sample of only one specimen of one of the diversity groups is sufficient for that taxon to be

Table 1. Minimum level of identification in Danish Stream Fauna Index (DSFI).

Taxonomic group	Taxa used in Danish Stream Fauna Index (DSFI)
Turbellaria (flatworms)	Tricladida
Oligochaeta (true worms)	Tubificidae, Oligochaeta
Hirudinea (leeches)	*Helobdella, Erpobdella*
Malacostraca (crustaceans)	*Asellus, Gammarus*
Plecoptera (stoneflies)	*Amphinemura, Brachyptera, Capnia, Isogenus, Isoperla, Isoptena, Leuctra, Nemoura, Nemurella, Perlodes, Protonemura, Siphonoperla, Taeniopteryx*
Ephemeroptera (mayflies)	Ametropodidae, Baetidae, Caenidae, Ephemeridae, Ephemerellidae, Heptageniidae, Leptophlebiidae, Siphlonuridae
Megaloptera (alder-fly)	*Sialis*
Coleoptera (beetles)	*Elmis, Limnius, Elodes*
Trichoptera (caddis larvae) with cases	Beraeidae, Brachycentridae, Hydroptilidae, Goeridae, Glossosomatidae, Leptoceridae, Lepidostomatidae, Limnephilidae, Molannidae, Odontoceridae, Phryganeidae, Sericostomatidae
Trichoptera (caddis larvae) without cases	Ecnomidae, Hydropsychidae, Philopotamidae, Polycentropodidae, Psychomyiidae, Rhyacophilidae
Diptera (flies and midges)	Psychodidae, *Chironomus*, Chironomidae, Eristalini, Simuliidae
Gastropoda (snails)	*Ancylus, Lymnaea*
Lamellibranchia (mussels)	*Sphaerium*

Table 2. Danish Stream Fauna Index (DSFI). The index value (fauna class) is a function of occurrence of selected indicator taxa in combination with the number of diversity groups.

Indicator groups (IG)		DSFI index value			
		≤ –2 diversity groups	–1 to 3 diversity groups	4 to 9 diversity groups	≥10 diversity groups
Indicator Group 1 (IG 1):					
Brachyptera, Capnia, Leuctra, Isogenus,					
Isoperla, Isoptena, Perlodes, Protonemura	≥ 2 taxa	–	5	6	7
Siphonoperla,					
Ephemeridae,					
Limnius,					
Glossosomatidae, Sericostomatidae.	1 taxon	–	4	5	6
Indicator Group 2 (IG 2):					
Amphinemura, Taeniopteryx, Ametropodidae,					
Ephemerellidae, Heptageniidae,					
Leptophlebiidae, Siphlonuridae,					
Elmis, Elodes,					
Rhyacophilidae, Goeridae,		4	4	5	5
Ancylus					
If *Asellus* ≥5 go to IG 3.					
If Chironomus ≥5 go to IG 4					
Indicator Group 3 (IG 3):					
Gammarus ≥10,					
Caenidae,		3	4	4	4
Other Trichoptera ≥5					
If Chironomus ≥ 5 go to IG 4					
Indicator Group 4 (IG 4):					
Gammarus ≥10,	≥2 taxa	3	3	4	–
Asellus,					
Caenidae					
Sialis,	1 taxon	2	3	3	–
Other Trichoptera					
Indicator Group 5 (IG 5):					
Gammarus <10	≥2 taxa	2	3	3	–
Baetidae					
Simuliidae ≥25	1 taxon or if				
If Oligochaeta ≥100 go to IG 5, 1 taxon	Oligochaeta	2	2	3	–
If Eristalini ≥ 2 go to IG 6	≥100				
Indicator Group 6 (IG 6):					
Tubificidae					
Psychodidae		1	1	–	–
Chironomidae					
Eristalini					

included as a diversity group. An exception is Oligochaeta, for which ≥100 individuals have to be present.

The index value is determined as follows. The number of diversity groups is found. The fauna list is then examined for any invertebrates belonging to IG 1. If there are any specimens present in the required numbers, the index value is that given in Table 2, where the row representing IG 1 crosses the column corresponding to the number of diversity groups. If no taxa belonging to IG 1 are present, the pro-

Table 3. Positive and negative diversity groups in Danish Stream Fauna Index (DSFI).

Diversity groups	
Positive	Negative
Tricladida	Oligochaeta ≥100
Gammarus	*Helobdella*
Every genus of Plecoptera	*Erpobdella*
Every family of Ephemeroptera	*Asellus*
Elmis	*Sialis*
Limnius	Psychodidae
Elodes	*Chironomus*
Rhyacophilidae	Eristalini
Every family of case-bearing Trichoptera	*Sphaerium*
Ancylus	*Lymnaea*

cedure is repeated for IG 2, etc. In IGs 1, 4 and 5, the upper row should be used if two or more indicator taxa are present, while the lower row should be used if only one indicator taxon is present.

In IGs 2, 3 and 5, certain taxa are used to preclude the entrance into these IGs (Table 2). This is the case in IG 2, when *Asellus* and/or *Chironomus* are found in the kick sample in numbers ≥5. In IG 3, this is also the case when *Chironomus* are present in numbers ≥5. In IG 5, Eristalini is used in the same way when there are ≥2 specimens. Furthermore, if numbers of Oligochaeta are ≥100 in IG 5, only the lower row is to be used. Some examples on the determination of the DSFI index value are given in Table 4.

Special principles in DSFI

Despite the similarities with other biotic indices such as BBI (De Pauw & Vanhooren 1983) and EBI (Italian modification) (Ghetti 1997), three principles are unique to the DSFI.

As mentioned earlier, both positive and negative diversity groups are used. This procedure was selected by Andersen et al. (1984) because it was found to provide the best separation of index values in the centre of the scale.

Secondly, the principle of using specific taxa to preclude entrance into IG 2 (*Asellus* and *Chironomus*), IG 3 (*Chironomus*) and IG 5 (Oligochaeta and Eristalini) is specific to the DSFI. The reason is that *Asellus*, *Chironomus*, Oligochaeta and Eristalini are associated with organic pollution and the presence of these pollution-tolerant taxa thus indicates that the index value should be lower.

Thirdly, it is important to point out that specimens from the kick samples and qualitative hand-picked samples from stones and large wooden debris constitute one fauna sample, but are used separately in the computation of the index value as mentioned above.

DSFI compared to other biotic indices

The biotic indices used in Belgium (De Pauw & Vanhooren 1983), Italy (Ghetti 1997) and France (NF T 90–350 1992) are those most similar to the DSFI. The methods used in Belgium (BBI) and Italy (EBI-Italian modification) are based on rather undifferentiated indicator groups. At the same time, the level of identification in both BBI and EBI is to the genus level in the case of Plecoptera and Ephemeroptera. When computing the index value of BBI and EBI, this detailed information is used at the level of the diversity groups. However, at the level of indicator groups the same detailed information is only used to a rather limited degree. In contrast, the DSFI, like the French method (IBGN), uses the collected information in more differentiated indicator groups, where genus and families of Plecoptera, Ephemeroptera, Trichoptera, etc. are combined into individual indicator groups according to their tolerance levels. Such a differentiated construction of indicator groups is also found in the two score systems BMWP and BMWP′ used in England and Spain (Armitage 1983, Alba-Tercedor & Pujante 2000).

Use of DSFI in the future

Monitoring of running waters under the Nationwide Monitoring Programme has been revised for the period 1998–2003, the strategy being changed from biological monitoring of mainly large streams and rivers to a net of national sites representative at the level of stream size, geographical distribution, ecological quality, etc. Since 1999 the number of sites

Table 4. Examples on determination of the Danish Stream Fauna Index value. The relevant indicator group (IG) and the number of diversity groups are shown at the bottom of the table. The following abbreviations are used. Ex., example; Kick, kick sample; Hand, hand-picked sample; pos, positive diversity groups (•); neg, negative diversity groups (♦). Specimen numbers of taxa used as entrance points in Indicator Groups (IG) are shaded.

	Ex. 1		Ex. 2		Ex. 3		Ex. 4		Ex. 5		Ex. 6	
	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand
Tricladidae												
• Tricladida	9	1			1	3			3	1		
♦ Oligochaeta												
Naididae	3		62				10		44			
Tubificidae	33	2	592		20	1	83		93	4	36	
Lumbriculus			2				18					
Hirudinea												
Glossiphonia					5	1						1
♦ *Helobdella*			2		1		4		1		2	
♦ *Erpobdella*					10	2		2			3	1
Hydracarina	7				56				17		46	
Crustacea												
Ostracoda			13									
♦ *Asellus*			15		4	2	8				17	
• *Gammarus*	236	3			512	2	37		144	2	616	
Ephemeroptera												
• Baetidae	228	12			30				152	9	908	
• Heptageniidae	1											
• Ephemerellidae											2	
• Leptophlebiidae												
• Ephemeridae	12	6										
Plecoptera												
• *Amphinemura*		1							5			
• *Nemoura*	46	20			2	3			64	16	9	
• *Nemurella*									4			
• *Protonemura*	1								32	4		
• *Leuctra*										1	1	
Corixidae							1					
Coleoptera												
Dytiscidae					4				1	1	45	
Hydraenidae	3											
Hydrophilidae		1										
• *Elodes*	57	1						1				
• *Elmis*	30				1		2				2	
Sialidae												
♦ Sialis											1	
Trichoptera												
• Rhyacophilidae	5	9				1			14	5		1

Table 4. *contd.*

	Ex. 1		Ex. 2		Ex. 3		Ex. 4		Ex. 5		Ex. 6	
	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand
• Glossosomatidae	2											
Polycentropodidae					1				3	3	1	
Hydropsychidae	8	12			42	2	4		26	4	3	1
• Beraeidae	1											
• Sericostomatidae		1										
• Goeridae	5	1										
• Limnephilidae	3	6			34	8			12	10	1	
Diptera												
Limoniidae	30	4	7		5				26	2	6	
• Psychodidae	2								4			
Ptychopteridae	3	5							2			
Simuliidae	16	16			1		175		232		779	
Ceratopogonidae	1	1			3		4		11			
Tanypodinae	1				2				8		10	
Diamesinae	5						1					
Prodiamesinae		1			1		1		48	1		
Orthocladiinae	34	10	3		126	9	77		280	9	178	1
Chironominae, ex. *Chironomus*	17		1		1				265	10	2	
• *Chironomus*			106				7					
Empididae									11			
Atherix									1			
Mollusca												
Physa						1						
Valvata			3									
Anisus							5					
• *Lymnaea*				1			9		5			
Planorbis				1			1					
• *Ancylus*	4	3			4	1				3		
Pisidium	67	3	10				1		4		1	
• *Sphaerium*			4				6					
Indicator Group (IG)	IG 1		IG 4		IG 2		IG 4		IG 1		IG 3	
(number of taxa)	(3 taxa)		(1 taxon)		(2 taxa)		(3 taxa)		(2 taxa)		(2 taxa)	
Diversity groups (pos – neg)	17 – 1 = 16		0 – 6 = –6		8 – 3 = 5		3 – 7 = –4		11 – 4 = 7		8 – 4 = 4	
DSFI index-value	7		2		5		3		6		4	

has increased from 444 to 1053. DSFI will be applied at these sites once yearly (spring samples). If site continuity can be assured, it will be possible to make objective comparisons of inter-regional and temporal differences. Apart from its use in the Nationwide Monitoring Programme, the DSFI is also recommended as the official method for use by the regional authorities when controlling compliance of quality objectives for running waters.

References

AFNOR NF T 90–350, 1992: *Essais des eaux. Détermination de l'indice biologique global normalisé (IBGN).* – NF T 90–350. Décembre 1992, 9 pp.

ALBA-TERCEDOR, J. & PUJANTE, A. 2000: Running-water biomonitoring in Spain: opportunities for a predictive approach. – In: WRIGHT, J. F., SUTCLIFE, D. W. & FURSE, M. T. (eds): *Assessing the biological quality of fresh waters: RIVPACS and other techniques.* Freshwater Biological Association, Ambleside, Cumbria, UK, pp. 207–216.

ANDERSEN, M. M., RIGET, F. F. & SPARHOLT, H., 1984: A mod-

ification of the Trent Index for use in Denmark. – *Water Res.* 18(2): 145–151.

ARMITAGE, P. D., MOSS, D., WRIGHT, J. F. & FURSE, M. T., 1983: The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. – *Water Res.* 17: 333–347.

DANISH ENVIRONMENTAL PROTECTION AGENCY, 1998: *Biological assessment of watercourse quality. Guidelines, No. 5.* – Danish Environmental Protection Agency, Ministry of Environment and Energy, Copenhagen, 39 pp (in Danish).

DE PAUW, N. & HAWKES, H. A. 1993: Biological monitoring of river water quality. – In: WALLEY, W. J. & JUDD, S., (eds): *River Water Quality Monitoring and Control*: 87–111. – Aston University.

DE PAUW, N. & VANHOOREN, G., 1983: Method for biological quality assessment of watercourses in Belgium. – *Hydrobiologia* 100: 153–168.

DE PAUW, N., GHETTI, P. F., MANZINI, P. & SPAGGIARI, R. 1992: Biological assessment methods for running waters. – In: NEWMAN, P. J., PIAVAUX, M. A. & SWEETING, R. A. (eds): *River water quality – Ecological assessment and control*: . Commission of the European Communities, EUR 14606 EN-FR. Brussels, pp. 217–248.

FRIBERG, N., LARSEN, S. E., CHRISTENSEN, F., RASMUSSEN, J. V. & SKRIVER, J., 1996: *Dansk Fauna Indeks: Test og modifikationer* (in Danish). – Technical Report, No. 181, National Environmental Research Institute, Silkeborg, 58pp.

FRIEDRICH, G., 1990: Eine Revision des Saprobiensysstems. – *Z. Wasser Abwasser Forsch.* 23: 141–152.

GHETTI, P. F., 1997: *Manuale di applicazione. Indice Biotico Esteso (I.B.E.). I Macroinvertebrati nell controllo della qualità degli ambienti di acquae correnti.* – Provinzia Autonoma di Trento. Agenzia provinciale per la protezione dell'ambiente. Trento.

KIRKEGAARD, J., WIBERG-LARSEN, P., JENSEN, J., IVERSEN, T. M. & MORTENSEN, E., 1992: *Biologisk bedømmelse af vandløbskvalitet – Metode til anvendelse på vandløbsstationer i Vandmiljøplanens Overvågningsprogram* (in Danish). – Technical Guidelines No. 5, National Environmental Research Institute, Silkeborg, 22 pp.

KOLKWITZ, R. & MARSSON, M., 1902: *Grundsätze für die biologische Beurteilung des Wassers nach seiner Flora und Fauna.* – Mitt. kgl. Prüfanstalt Wasserversorgung Abwasserbeseitigung. Berlin-Dahlem, 1: 33–72.

METCALFE, J. L., 1989: Biological water quality assessment of running waters based on macroinvertebrate communities: History and present status in Europe. – *Environ. Pollut.* 60: 101–139.

MINISTRY OF AGRICULTURE, 1970: *Vejledning om fremgangsmåden ved bedømmelse af recipienters forureningsgrad* (in Danish). – Ministry of Agriculture, Copenhagen, 5 pp.

OLSEN, H. M. & FRIBERG, N., 1999: Biological stream assessment in Denmark: The importance of physical factors. – *Proc. Nordic Benthological Meeting in Silkeborg, Denmark. November 1997.*

SKRIVER, J., BAATTRUP-PEDERSEN, A. & LARSEN, S., 1997: Streams: Ecological quality. – In: WINDOLF, J. (ed.): *Freshwaters. Streams and springs, 1996. The Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment. Techinal Report No. 214:* 29–46. – National Environmental Research Institute, Silkeborg (in Danish).

WOODIWISS, F. S., 1964: The biological system of stream classification used by the Trent River Board. – *Chem. Ind.* 14: 443–447.

Authors' addresses:

J. SKRIVER, N. FRIBERG, Department of Streams and Riparian Areas, National Environmental Research Institute, Vejlsøvej 25, P.O. Box 314, DK-8600 Silkeborg, Denmark.

J. KIRKEGAARD, Danish Environmental Protection Agency, Strandgade 29, 1401 Copenhagen K, Denmark.