

Stream assessment in Denmark: the Danish Stream Fauna Index (DSFI)

Introduction

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), is currently being used as the national standard biomonitoring method (Danish Environmental Protection Agency 1998).

The Danish Stream Fauna Index 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). DSFI is currently used yearly at 1051 stations in the National Monitoring Programme for the Aquatic Environment NOVA 2003 (Bøgestrand 1999). In addition, DSFI is widely used by regional water authorities.

Although DSFI has proven to be sensitive towards several stressors (e.g. hydromorphological changes, low pH etc.), it has primarily been developed to detect the impact of organic pollution. All macroinvertebrate taxa used in DSFI are indicators of organic pollution either by being tolerant or sensitive towards low oxygen levels. The sensitivity of DSFI is therefore highest with respect to organic pollution. Organic pollution from urban areas is a major problem in Lithuanian streams and rivers. This is especially evident in densely populated areas and in stream and rivers with low summer discharges.

The sampling and sorting procedure, the necessary identification level, demand for enumeration and finally the calculation of the DSFI index value will be described in the following sections.

DSFI 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 x 25 cm opening and a tapering netbag with a mesh size of 0.5 mm (European Standard EN 27 828). 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 (Figure 1). If stream width is less than one meter, 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.

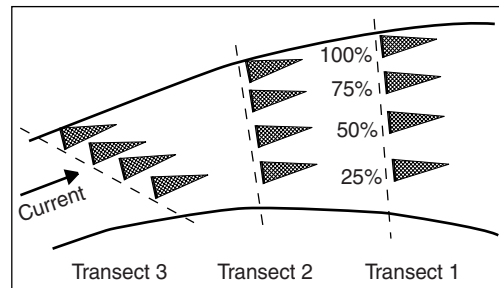


Figure 1: DSFI sampling methodology. Diagonally sampling (Transect 3) is undertaken if the stream width is less than 1 m.

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 minutes 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. The pooled kick sample should not in volume exceed 0.5 – 1 l. of material.

DSFI sorting, identification and counting

The macroinvertebrates are sorted and identified in the laboratory. No sub-sampling procedure is allowed. However, sorting and identification are 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 Table1.

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)	<i>Helobdella</i> , <i>Erpobdella</i>
Malacostraca (crustaceans)	<i>Asellus</i> , <i>Gammarus</i>
Plecoptera (stoneflies)	<i>Amphinemura</i> , <i>Brachyptera</i> , <i>Capnia</i> , <i>Isogenus</i> , <i>Isoperla</i> , <i>Isoptena</i> , <i>Leuctra</i> , <i>Nemoura</i> , <i>Nemurella</i> , <i>Perlodes</i> , <i>Protonemura</i> , <i>Siphonoperla</i> , <i>Taeniopteryx</i>
Ephemeroptera (mayflies)	Ametropodidae, Baetidae, Caenidae, Ephemeridae, Ephemerellidae, Heptageniidae, Leptophlebiidae, Siphonuridae
Megaloptera (alder-fly)	<i>Sialis</i>
Coleoptera (beetles)	<i>Elmis</i> , <i>Limnius</i> , <i>Elodes</i>
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, <i>Chironomus</i> , Chironomidae, Eristalinae, Simuliidae
Gastropoda (snails)	<i>Ancylus</i> , <i>Lymnaea</i>
Lamellibranchia (mussels)	<i>Sphaerium</i>

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 (see Table 3.).

Danish Stream Fauna Index (DSFI)		DSFI index value			
Indicator groups (IG) ↓	No. of diversity groups →	≤ -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, Siphonoperla, Ephemeridae, Limnius, Glossosomatidae, Sericostomatidae.	≥ 2 taxa	-	5	6	7
	1 taxon	-	4	5	6
Indicator Group 2 (IG 2): Amphinemura, Taeniopteryx, Ametropodidae, Ephemerellidae, Heptageniidae, Leptophlebiidae, Siphonuridae, Elmis, Elodes, Rhyacophilidae, Goeridae Ancyclus If <i>Asellus</i> ≥ 5 go to IG 3 If <i>Chironomus</i> ≥ 5 go to IG 4		4	4	5	5
Indicator Group 3 (IG 3): Gammarus ≥ 10, Caenidae Other Trichoptera ≥ 5 If <i>Chironomus</i> ≥ 5 go to IG 4		3	4	4	4
Indicator Group 4 (IG 4): Gammarus ≥ 10, Asellus, Caenidae, Sialis, Other Trichoptera	≥ 2 taxa	3	3	4	-
	1 taxon	2	3	3	-
Indicator Group 5 (IG 5): Gammarus < 10 Baetidae Simuliidae ≥ 25 If Oligochaeta ≥ 100 go to IG 5, 1 taxon If Eristalinae ≥ 2 go to IG 6	≥ 2 taxa	2	3	3	-
	1 taxon or if Oligochaeta ≥ 100	2	2	3	-
Indicator Group 6 (IG 6): Tubificidae Psychodidae Chironomidae Eristalinae		1	1	-	-

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

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

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	
<i>Lumbriculus</i>			2				18					
Hirudinea												
<i>Glossiphonia</i>					5	1						1
◻ <i>Helobdella</i>			2		1		4		1		2	
◻ <i>Erpobdella</i>					10	2		2			3	1
Hydracarina	7				56				17		46	
Crustacea												
Ostracoda			13									
◻ <i>Asellus</i>			15		4	2	8				17	
● <i>Gammarus</i>	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												
● <i>Amphinemura</i>		1							5			
● <i>Nemoura</i>	46	20			2	3			64	16	9	
● <i>Nemurella</i>									4			
● <i>Protonemura</i>	1								32	4		
● <i>Leuctra</i>										1	1	
Corixidae							1					
Coleoptera												
Dytiscidae					4				1	1	45	
Hydraenidae	3											
Hydrophilidae		1										
● <i>Elodes</i>	57	1						1				
● <i>Elmis</i>	30				1		2				2	

Table 4. (continued)

	Ex. 1		Ex. 2		Ex. 3		Ex. 4		Ex. 5		Ex. 6	
	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand	Kick	Hand
Sialidae												
☐ <i>Sialis</i>											1	
Trichoptera												
● Rhyacophilidae	5	9				1			14	5		1
● Glossosomatidae	2											
					1				3	3	1	
Polycentropodidae												
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. <i>Chironomus</i>	17		1		1				265	10	2	
☐ <i>Chironomus</i>			106				7					
Empididae									11			
<i>Atherix</i>									1			
Mollusca												
Physa						1						
Valvata			3									
Anisus							5					
☐ <i>Lymnaea</i>				1			9		5			
<i>Planorbis</i>				1			1					
● <i>Ancylus</i>	4	3			4	1				3		
<i>Pisidium</i>	67	3	10				1		4		1	
☐ <i>Sphaerium</i>			4				6					
Indicator Group (IG) (number of taxa)	IG 1 (3 taxa)		IG 4 (1 taxon)		IG 2 (2 taxa)		IG 4 (3 taxa)		IG 1 (2 taxa)		IG 3 (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	

DSFI calculation

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 6 indicator groups (IG's) – (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 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 procedure 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, Eristalinae 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 of the determination of the DSFI index value are given in Table 4.

DSFI principles and other indices

The sampling methodology in DSFI is based on a multihabitat approach where most of the available habitats will be sampled. This is an advantage in terms of estimating species richness, as some species will only be found in one or a few habitats. The different habitats are not kept separate when applying the DSFI method as all kicks are pooled to one sample. Some other assessment methods used internationally differs in this respect as they only sample one habitat (in which case always riffles), keep samples separate or take replicate samples from the same habitat (e.g. Skriver 2000). However, a Nordic comparison showed that the evaluation of results using

various sampling methodologies (including DSFI) was not significantly different as long as a CEN standard kick net were used.

Despite the similarities with other biotic indices like 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 Eristalinae) is specific to the DSFI. The reason is that *Asellus*, *Chironomus*, Oligochaeta and Eristalinae 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.

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).

References

AFNOR (1992; 2004): Norme IBGN. NF T 90-350.

Alba-Tercedor, J. & Pujante, A. (2000): Running water biomonitoring in Spain: opportunities for a predictive approach. In: Wright J.F., Sutcliffe D.W. & Furse M.T. (Eds.): Assessing the biological quality of fresh waters – RIVPACS and other techniques: 207-216. Freshwater Biological Association. Titus Wilson & Son. Kendal, Cumbria.

Andersen, M.M., Riget F.F. & Sparholt H. (1984): A modification of the Trent Index for use in Denmark. - Water Res: 18, No 2: 145-151.

Armitage, P. D., D. Moss, J. F. Wright & M. T. Furse. (1983): The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Research 17: 333-347.

Bøgestrand (1999): Vandløb og kilder 1998-NOVA 2003. Danmarks Miljøundersøgelser. Faglig rapport fra DMU, nr. 292 1999. Danish Environmental Research Institute, Silkeborg, Denmark.

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

De Pauw, N. & Vanhooren, G. (1983): Method for biological quality assessment of watercourses in Belgium. - *Hydrobiologia* 100: 153-168.

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

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

Skriver, J. (2000): Biological monitoring in Nordic rivers and lakes. TemaNord 2001: 513. Nordic Council of Ministers, Copenhagen, 109pp.