IMPLEMENTATION OF THE WATER FRAMEWORK DIRECTIVE TO THE ECOLOGICAL ASSESSMENT OF LAKES USING MACROZOOBENTHOS ASSEMBLAGES

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Keywords: lakes, typology, ecological status, macro-invertebrates, Water Framework Directive

Abstract

A case study on the ecological assessment of lakes on the basis of benthic macroinvertebrates is presented. Sampling, statistical data analysis, and the approach to the identification of reference lakes and reference invertebrate assemblages are described and critically discussed. Difficulties in the implementation of the Water Framework Directive following from this case study are highlighted, especially those related to the assessment of the degradation levels of the ecological status. For that problem, an alternative approach is proposed.

1. Introduction

The EU-Water Framework Directive (WFD - Directive 2000/60/CE) provides a legal framework for the sustainable management of inland and costal waters in Europe. The basic concept of the WFD is to consider water bodies as aquatic ecosystems requiring a holistic approach in assessing their ecological status. Consequently, actions of restoration and preservation must be based on detailed information on the whole ecosystem (Article 1).
However, previous to any actions of restoration, the WFD logically imposes to assess the current ecological status of the aquatic ecosystems. The approach proposed is based on the comparison of the actual ecological conditions with type-specific reference conditions. Technically, the method runs by three steps:

1- For each eco-region, (Annex XI of the Water Framework Directive), the types have to be defined according to the geographical and morphological characteristics of the aquatic ecosystems. However, each type must be related to specific biological characteristics.

2- For each type, type-specific reference conditions have to be defined. This includes the description of biological reference assemblages and diversity, but also of hydro-morphological and physico-chemical reference conditions, which will support the biological parameters in the assessment of the ecological status of the water bodies.
3- For each water body, the ecological status has to be assessed by comparison to the type-specific reference conditions.

However, the current strong ecological degradation of most of the aquatic ecosystems in Europe makes this method difficult to apply. At the present time, the most challenging point is to find undisturbed type-specific reference aquatic ecosystems. If reference ecosystems are lacking, the WFD says that biological type-specific reference conditions can be defined using predictive models or hindcasting methods based on historical or palaeological data. However, the multiplicity of responses of the macroinvertebrate assemblages to environment specificities renders such models and methods imprecise.

This paper provides a case study on the ecological assessment of lakes based on macro-invertebrates, in application to the Water Framework Directive. The results, based on a study of 10 lakes, are a part of a larger project funded by the Landesumweltamt Brandenburg, which aims to assess the ecological status of 30 lakes in Brandenburg. In addition to the results, we want to describe the technical and conceptual difficulties we met in order to contribute to the current discussion on the typology and ecological assessment of lakes.

2. Materials and Methods

2.1 Sampling method

A special sampling method had been developed by Böhmer and Baier (2001) for the assessment of the ecological status of lakes in the framework of the WFD. The sampling of the Brandenburg lakes was based on this method with some adaptations.
In each lake, macrozoobenthos was sampled in 6 sectors with 6 replicates from the infraprofundal to the littoriprofundal zones (1.5 to 6 m), using an Ekman-Birge grab sampler (total sampling area: 0.127 m²). In order to consider all the sediment types present, the sectors were alternatively prospected in their shallowest part (1.5-2.5 m depth) and in their deepest part (4-6 m depth). Sediments were sieved immediately in situ. Muddy sediments were rinsed using a sieve of 355 µm mesh size, which allowed to reduce the volume of sediment to process at the laboratory and consequently to pick the organisms more easily and quickly. Previous comparisons did not shown any differences in the density

and diversity of the fauna from muddy samples if fractions of the same sample were rinsed with a sieve of 200 µm mesh size or of 355 µm mesh size. Other types of sediments were rinsed using the sieve of 200 µm mesh size.
Most of the organisms were identified to the species level, except for Oligochaeta and Nematoda, which were identified to the class level, and for Diptera which were identified to the genus level. Two sampling campaigns were carried out in autumn 2001 and in spring 2002. The preliminary results presented here are only based on the fall sampling.
In order to test the quality of the sampling, we used the Hurlbert´s rarefaction curves (Hurlbert 1971), which plot the species number versus the specimen numbers (Fig.1). The curves show that the total diversity of the infraprofundal to the littoriprofundal zones was completely recorded. The sampling method used for bottom sediments (six sectors and six replicates per sector) seems thus to be suitable.

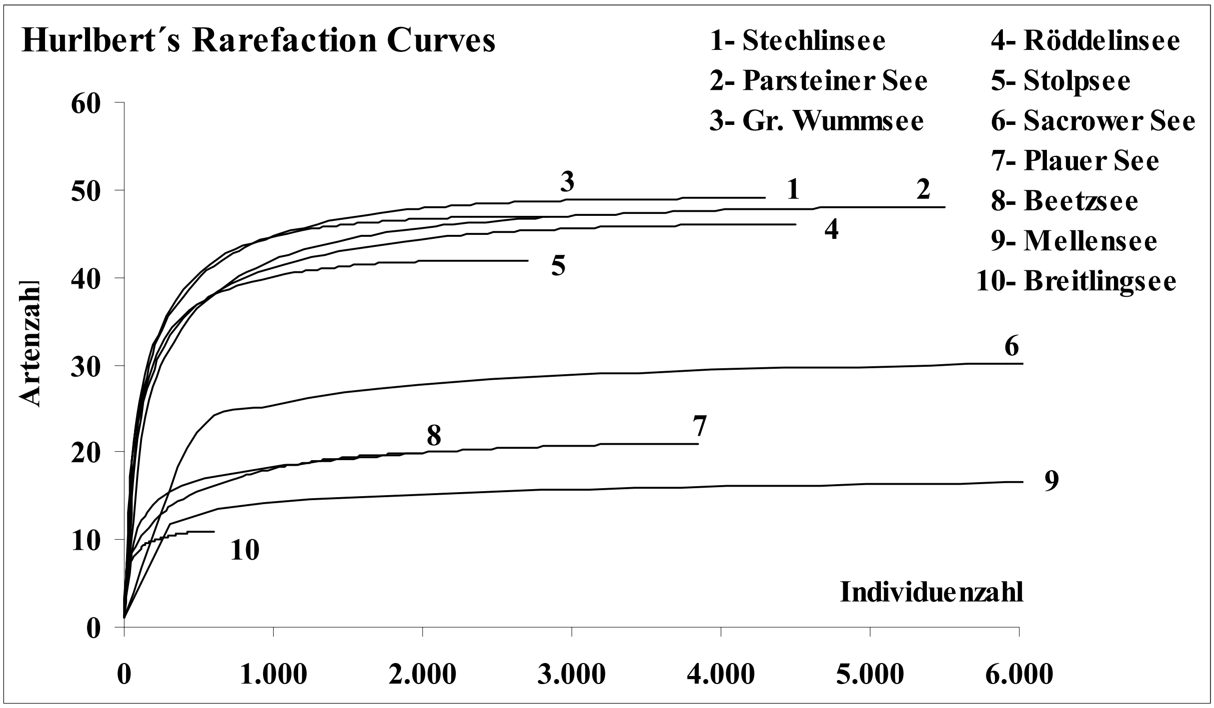

Figure 1: Hurlbert´s rarefaction curve. Infraprofundal to littoriprofundal fauna.

2.2 Statistical method

The data analysis had two objectives. The first objective was to obtain a lake typology using the biological data, the second objective was to identify the faunistical assemblages on which the biotypology is based. The main problem in the identification of faunistical assemblages is that many species from lakes have a large ecological valence and thus occur in more than one lake type. Additionally, the natural heterogeneity of biotopes possibly provides a variety of

niches which allow many adapted species to be present. In these conditions, it is then not easy to identify which species belongs truly to which type of lake.
Multivariate statistical analysis was used as a tool to establish the faunal reference assemblages because of its potential to ordinate the data in a multidimensional space. In the present work, we used a Correspondence Analysis (CoA - Benzecri 1983). The mathematical process used in this analysis organises the samples in order to get the lowest total variance as possible for the complete data set. Samples are then organised in a multidimensional space where each dimension represents one of the factors structuring the samples. As the first dimensions hold the highest structuring power, the resulting multidimensional cloud is projected, for an easier graphic interpretation, on the plan defined by the two first dimensions. Then, plotting of both lakes and species factorial scores (coordinates of each samples in the multidimensional space) in the two first axis factorial plan allows to define graphically which species belongs to which lake by comparison of distances between dots. The analysis were processed using ADE-4 Software (Chessel & Doledec 1993). Species represented by less than 5 individuals/m² have been removed from the data set prior to the CoA analysis. The data processing uses the raw density of each taxa weighted by its maximal density. Absolute abundances were transformed into percentages.

3. Results

3.1 Identification of types

The Water Framework Directive proposes two systems (A and B) to define the type of each lake (Annex II - § 1.2.2 of the WFD).
System A is based on 4 abiotic characteristics of the lakes : altitude, mean depth, surface area and geology. System B includes these 4 variables as "Obligatory factors" and a list of additional abiotic characteristics as "Facultative factors". We chose here to use the system A.
Brandenburg is located in the fourteenth ecoregion "Central plains" which belongs to altitudes below 200 m height above sea level. The surface area of the 10 studied lakes comprises between 1-10 km² and their calcium content is over 55 mg l^{-1}. The 10 studied lakes are thus all considered as calcareous. Finally, the use of system A results in the differentiation of the 10 lakes into 3 types mainly based on the mean depth (Tab.1). **Type I** relates to lakes deeper than 15 m, **type II** to lakes of which the depth is between 15 and 3 m, and **type III** to lakes shallower than 3 m depth.

Table 1: General characteristics and type identification of the 10 Brandenburg lakes. "-": no river connection, "+": connection with small, undisturbed river, "++": connection with

disturbed river. Md: Mud, Ma: Macrophytes, Sd: Sand, Ds: Shell of *Dreissena*, Wd: Woody debris. Types based on system A of the WFD.

	Trophic status	Surface area (km²)	Mean depth (m)	Max depth (m)	Ca Content ($mg.l^{-1}$)	River link	Bottom Substrat type	Type
Stechlinsee	Oligo	4.25	22.8	68.5	51	-	Md-Ma-Wd	**I**
Röddelinsee	Eu	1.83	> 15	35	70	+	Md-Sd	**I**
Sacrower See	Eu	1.07	18	36	54	-	Md	**I**
Gr. Wummsee	Oligo	1.48	11.8	36	43	-	Md-Ma	**II**
Parsteiner See	Meso	10.03	7.7	31	55	-	Md-Ma-Ds	**II**
Stolpsee	Eu	3.81	> 3	15	69	+	Md-Ds-Wd	**II**
Beetzsee	Poly	3.98	< 3	5.50	82	-	Md	**III**
Breitlingsee	Poly	5.13	< 3	4.50	94	++	Md	**III**
Mellensee	Poly	2.15	3.3	10	73	++	Md	**III**
Plauer See	Poly	6.66	< 3	10	94	++	Md	**III**

3.2 Identification of type-specific lakes of reference

Following the identification of types, type-specific reference lakes free of anthropogenic disturbances have to be found for each type. However, these type-reference lakes do not necessarily exhibit oligotrophic conditions. As land is the end-point of natural evolution of lakes on the long term, they naturally change from the oligotrophic to the mesotrophic, and finally to the dystrophic status. Type-reference lakes will thus include not only oligotrophic but also some naturally mesotrophic and dystrophic lakes. Some lakes with special abiotic conditions (shallow but with a big catchment area) can also be naturally slightly eutrophic in undisturbed landscapes (I. Schönfelder, Pers. Mitt.).
Three lakes were assigned to **type I**: Stechlinsee, Röddelinsee and Sacrower See. Stechlinsee is an oligotrophic lake. It is surrounded by forests and located in a nature protected area. Röddelinsee and Sacrower see are two eutrophic lakes. Röddelinsee is surrounded by agricultural cropland and receives water from a canal (Templiner Kanal) which passes the city of Templin (14 000 inhabitants). Sacrower See is located in a large wooded and long-term protected area close to Potsdam. Nevertheless, it is eutrophic, probably due to some indirect underground inputs of nutrients from Postdam. Hence, only Stechlinsee can be reasonably considered as provisional reference lake for type I.
Three lakes belong to **type II**: Grosser Wummsee, Parsteiner See and Stolpsee. Gr. Wummsee is an oligotrophic lake. It is surrounded by forests and preserved since a long time from major anthropogenic influences. Parsteiner See and

Stolpsee are mesotrophic and eutrophic. Parsteiner See is surrounded by agricultural cropland. Stolpsee, as Gr. Wummsee, is also surrounded by forests but the Havel River, coming from Fürstenberg (4 600 inhabitants), passes through. Its bottom is mainly muddy. It is thus clear that Parsteiner See and Stolpsee can not be used as reference lakes for type II. Thus, Gr. Wummsee can be taken as a provisional reference lake for type II in Brandenburg.
Four lakes belong to **type III**: Beetzsee, Breitlingsee, Mellensee and Plauer See. All are strongly affected by human activities. They are located in agricultural areas and/or close to large cities of more than 20 000 inhabitants. Breitlingsee and Plauer See are crossed by the lower part of the Havel River which is used for intensive barge navigation. According to this situation, none of these 4 lakes can be used as reference lake for the type III.
In conclusion, only two lakes can finally be adopted as type-specific reference lakes in the framework of this paper: the Stechlinsee for type I and the Gr. Wummsee for type II. The difficulty to find undisturbed type-specific reference lakes for each type is here clearly highlighted, as finally only for 6 of the 10 lakes studied a type-reference lake could be assigned, which permits their assessment by comparison to biological type-specific reference conditions.

3.3. Type specific biological reference conditions

The final aim of the identification of type-specific reference lakes is to describe the type-specific biological conditions which will be used as reference in the assessment of the current ecological status of lakes. For lakes, type-specific biological reference conditions have to be defined for four groups of organisms, called "Biological Quality Elements": Phytoplankton, macrophytes and phytobenthos, benthic invertebrate fauna and fish fauna (Annex V, § 1.2.2 of the WFD).
The type-specific biological reference conditions for the "Benthic invertebrate fauna" include three components: the taxonomic composition and abundance of the fauna, the ratio of disturbance sensitive taxa to insensitive taxa, and the level of diversity of the fauna. In this preliminary work, only the taxonomic composition, the abundance and the level of diversity of the fauna will be considered.

3.3.1. Type-specific reference assemblages

The correspondence analysis (CoA) visualizes the ordination of the 10 studied lakes in a two-dimensional plan (Fig.2).

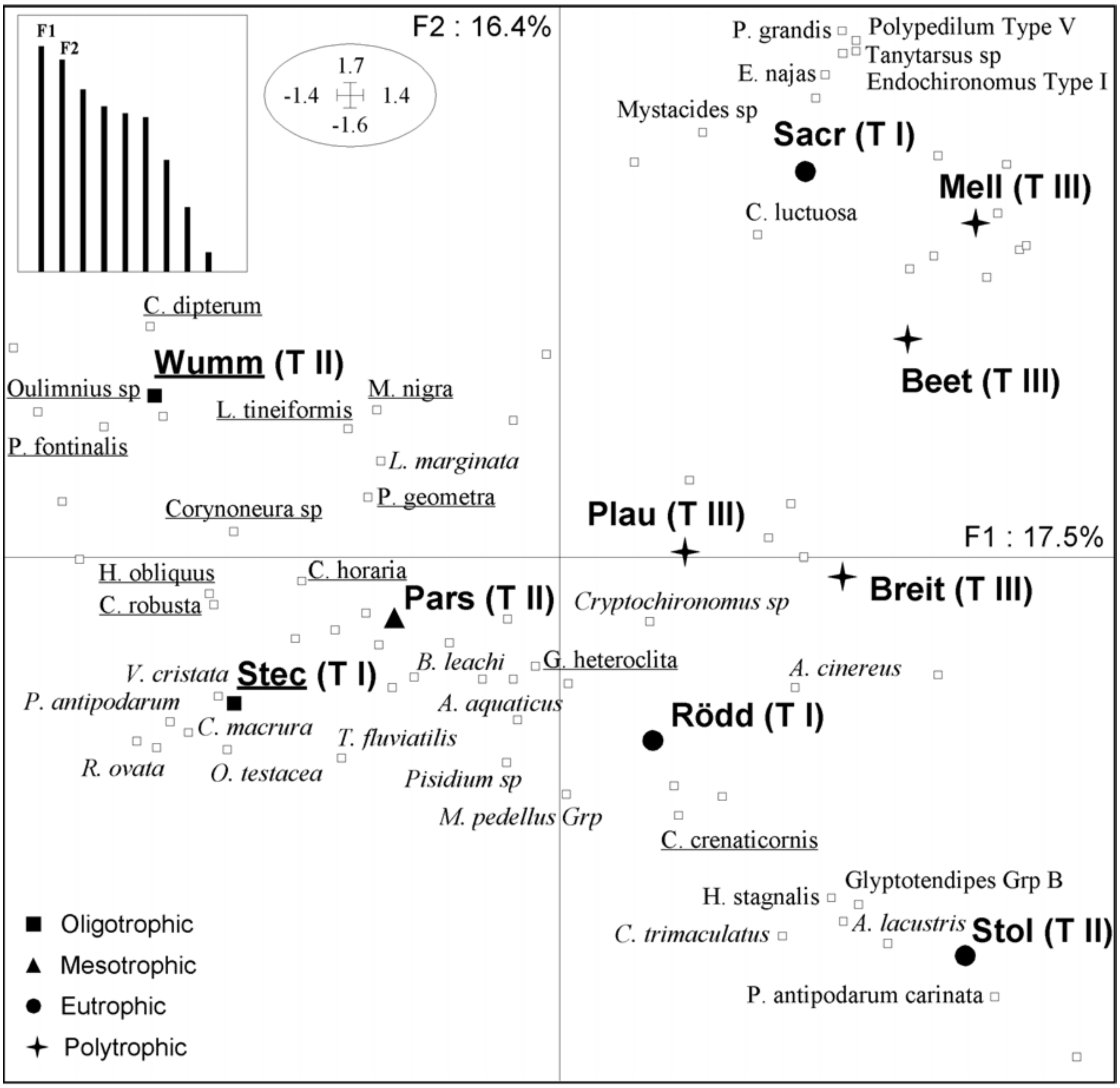

Figure 2: Projection of the factorial scores of both lakes (Closed geometrical forms) and species (Open squares) on the F1xF2 factorial plan of the CoA analysis. Infraprofundal and littoriprofundal macroinvertebrate communities, autumn 2001. Type-reference lakes underlined. Reference species for type I italicised, reference species for type II underlined. Other species are species cited in the text. For chironomids, subgenus groups and types were taken from Pinder and Reiss (1983).

The lakes are organised along the F1 axis according to their trophic status. This axis clearly separates eutrophic to polytrophic lakes (positive coordinates) from oligo- to mesotrophic lakes (negative coordinates). The trophic status explains 17.5% of the total variance of the analysis. The F2 axis organises the lakes according to the abiotic typology (Fig.2). Lakes from type I, type II and type III are successively represented along the F2 axis. However, there are two exceptions. One is the Sacrower See (Type I), which is isolated and far from the other lakes of type II (Stechlinsee and Röddelinsee). The graphic positioning of the Sacrower See is due to the presence of 7 taxa which were especially abundant in Sacrower See (Fig.2): *Endochironomus Type I* (8 785 Ind./m²), *Polypedilum Type V* (4 846 Ind./m²), *Tanytarsus sp* (2 395 Ind./m²), *Caenis luctuosa* (152 Ind./m²), *Phryganea grandis* (55 Ind./m²), *Erythroma najas* (35 Ind./m²) and *Mystacides sp* (26 Ind./m²) (The types mentioned here refer to groups of genus according to Pinder and Reiss 1983). The special situation and the long term protection of the Sacrower See allowed the development of a peculiar fauna which is pointed out by the analysis. However, according to its geomorphological characteristics, there is no doubt about the affiliation of Sacrower See to type I.

The second exception is Stolpsee (Type II), which is strongly isolated and far from Parsteiner See, the nearest lake of type II. The macroinvertebrate composition of Stolpsee shows some similarities with the faunal assemblage of the Röddelinsee (Type I). The presence of four species contribute strongly in the CoA analysis and causes Röddelinsee and Stolpsee to be arranged into the lowest part of the F2 axis (Fig.2). These species are more or less abundant in both lakes but quasi-absent from the other lakes: *Helobdella stagnalis* (94 Ind./m² on Stolpsee and 42 Ind./m² in Röddelinsee), *Cyrnus trimaculatus* (31 and 8 Ind./m²), *Potamopyrgus antipodarum carinata* (21 and 5 Ind./m²) and *Glyptotendipes* Grp B (9 and 9 Ind./m²). As a distinctive feature, Röddelinsee and Stolpsee are both in connection with an undisturbed river. Stolpsee is crossed by the Upper Havel River and Röddelinsee by the small Templiner Kanal. The four species listed above are not especially characteristic for running water and, in any case, flow velocities in the Upper Havel and of the Templiner Kanal are low. Yet, these four species found some similar living conditions in Stolpsee and Röddelinsee. *C. trimaculatus* and *H. stagnalis* are euryoecious species and *Glyptotendipes* from Group B are well known to be plant miners. The only species which is related with running water is *P. antipodarum carinata*, as it is an invasive neozoon from New Zealand. Its presence in Röddelinsee and Stolpsee should be due to boat traffic travelling through the waterway. According to its depth and its calcium content, it is sure that Stolpsee belongs to a type II and not to a type I. Consequently, based on the actual results, it is not yet clear if Stolpsee and Röddelinsee can be grouped together because they are connected to undisturbed rivers. However, a possible explanation for their similar faunal assemblages is that lakes crossed by rivers represent an extra type for which we have, for the moment, no type-specific reference lake.

Based on the correspondence analysis, it is also possible to discuss the type affiliation of the 4 polytrophic lakes (Beetzsee, Breitlingsee, Mellensee and Plauer See). In regard to the similarity of the faunal assemblages, Plauer See and Breitlingsee seem to be related with type II, while Beetzsee and Mellensee seem to be related to a third type (Fig.2).

It can be concluded that the biotypology is in agreement with the abiotic typology. Moreover, benthic assemblages provide additional information allowing to render the abiotic typology more precise. The second axis of the CoA explains 16.4% of the total variance of the analysis. Statistically, the difference between 17.5% for the first axis and 16.4% is not significant, which means that faunal assemblages reflect as well the abiotic typology as the ecological status of lakes. Finally, the results highlight the efficiency of the use of benthic assemblages for both biotypology and ecological assessment.

Type-specific reference assemblages are deduced from the correspondence analysis (Fig.2). In theory, type-specific assemblages of reference should only include species found mainly in a given type. However, the ecological valence of the species might be wider than the variance of the specific characteristics of a lake type, so that the species will be able to colonise various habitats in two different lake types. The first question is then how to define the criterion for the inclusion of species into a faunal reference assemblage? We propose to consider the following guidelines in the fixing of type specific reference assemblages:

1- Species which are recorded in many lakes (high frequency) cannot be used in type-specific reference assemblages because they are too eurytopic.
2- Species only found in one lake, even if they are abundant, can also not be included into type-reference assemblages because there always remains an uncertainty about their true affiliation to the type. They can be present only in this lake because they found some specific niches to live, but they could also be recorded in an other lake if the sampling effort would be increased. The only exception occurs if a lake type is represented only by one lake in an eco-region.
3- The ideal type-specific species of reference is the species abundant in the type-specific reference lake but also found, in lower densities, in all or some disturbed lakes from the same type.
4- It is known that an increase of the food availability promotes the productivity, e.g. of chironomids (Lenat 1983). Thus, the density of some mesosaprobic invertebrate taxa will increase when the lake shifts from oligotrophic to mesotrophic conditions. Consequently, species present in oligotrophic type-specific reference lakes and also present in mesotrophic lakes of the same type but in a higher abundance have to be also included.
5- If a species is identified as a type-specific species of reference for two different lake types, then it should be assigned to the lake type where it is more abundant.

Based on these guidelines, provisional type-specific species of reference for the types I and II were deduced (Fig.2 and Tab.3).

3.3.2. Level of diversity of the fauna

The biodiversity of each type-reference lake is evaluated by calculating the Log series α index (Fisher et al. 1943). In a mathematical point of view, this index is independent of the sample size, which allows to minimise the influence of disparities in the total number of specimens collected per samples. The diversity indices for the type reference lakes are given in Table 2.

Table 2: Littoriprofundal diversities of the type-specific reference lakes. R : species richness, N : densities (Ind.m²).

	Type I Stechlinsee	**Type II Gr. Wummsee**
R	49	47
N	4 416	2 939
R/LogN	13.5	13.6
Log series α	7.8	8

3.4 Assessment of the ecological quality of the 10 studied lakes

In order to assess the increasing degree of degradation of each water body in comparison to type reference conditions, the WFD defines five status levels: high, good, moderate, poor and bad ecological status (Annex V, § 1.2 of the WFD). The comparison is based on defined quality elements related to biological, hydromorphological and physico-chemical aspects. The classification of a water body into one of the status requires to check all of these quality elements.

3.4.1 Comparison with type-specific assemblages

The assessment of the ecological status of the lakes has to be based on a comparison to type-specific reference assemblages. The Table 3 compares the faunal assemblages for the lakes of types I and II.

In Röddelinsee (Type I), about 50 % of the type-specific reference species are missing from the faunal assemblage. Moreover, the missing species are those which have the higher abundances in the type-specific reference assemblage. According to the normative definitions of ecological status classifications for lakes given in the WFD (Annex V, § 1.2.2), only a moderate status can be assigned to the Röddelinsee. In Sacrower See, only three type-specific reference species were recorded, so that it is evaluated to be in a poor status.

Table 3: Comparison of the faunal assemblages to type-specific reference communities for the types I and II. Faunal densities in ind.m^{-2}. Type-specific reference lakes underlined,

densities in bold. Doubtful status assessment due to doubtful type affiliation of a lake in brackets.

		Type I			**Type II**	
	Stec.	Rödd.	Sacr.	**Wumm.**	Pars.	Stol.
Type I						
Caenis macrura	**286**			25		
Radix ovata	**139**					
Potamopyrgus antipodarum	**157**				31	
Bithynia leachi	**76**			13		
Leptophlebia marginata	**76**		47	11		
Pisidium sp.	**52**	34	5		29	
Athripsodes cinereus	**47**	26	26		29	
Microtendipes pedellus Grp.	**41**	110				
Cryptochironomus sp	**36**	93				
Theodoxus fluviatilis	**34**	21				
Asellus aquaticus	**26**	362		11	229	
Acroloxus lacustris	**18**					
Oecetis testacea	**13**	3				
Valvata cristata	**13**				9	
Cyrnus trimaculatus	**13**	8				
Type II						
Caenis robusta	273	39		**213**	382	
Caenis horaria		34		**133**	564	
Leptocerus tineiformis				**121**	209	
Cloeon dipterum				**106**		3
Oulimnius sp.	18			**103**	2	
Corynoneura	7	29		**74**	48	
Physa fontanalis				**40**	16	
Haliplus obliquus	34			**29**	67	
Cyrnus crenaticornis		3		**13**	49	66
Piscicola geometra	5			**11**	29	
Mystacides nigra				**9**	16	
Glossiphonia heteroclita		3		**7**	4	
Ecological status	**High**	Moderate	Poor	**High**	Good	(Poor)

In the Parsteiner See (Type II), only the reference species *Cloeon dipterum* is missing from the assemblage, so that, it is evaluated to be in good status. Conversely, only two type-specific species of reference of type II were recorded in the Stolpsee, which was thus evaluated to be in a poor status.

3.4.2 Comparison with type-specific diversity

The ecological status of each lake has also to be evaluated according to the decrease of the faunal diversity (Tab.4). Conversely to the comparison with the type-specific reference assemblages, it appears not so indispensable, in this approach, to know the type affiliation of the lake previously. The decrease in diversity is a normal consequence of the degradation of ecological quality. As a consequence, this method permits to define the ecological status of lakes of type III even if the type-reference diversity is not known.

Table 4: Comparison of the littoriprofundal diversities of the 10 studied lakes. R : species richness, N : densities (Ind.m²). Lakes of reference are underlined and in bold. Doubtful assessment due to doubtful type affiliation in brackets.

Type	**Type I**			**Type II**			**Type III**			
	Stec	**Rödd**	**Sacr**	**Wumm**	**Pars**	**Stol**	**Beet**	**Breit**	**Mell**	**Plau**
R	**49**	46	31	**47**	48	42	20	11	17	21
N	**4 416**	4 593	25 134	**2 939**	5 651	2 787	4 416	626	15 908	3 954
R/LogN	**13.5**	12.6	7	**13.6**	12.8	12.2	6	3.9	4	5.8
Log series α	**7.8**	7.1	3.5	**8**	7.1	7	3.1	1.9	1.9	3
Status	**High**	Good	Poor	**High**	Good	(Good)	Poor	Bad	Bad	Poor

3.4.3 Ecological status of the 10 studied lakes

Merging the lake assessments based on type-specific assemblages and on type-specific level of diversity, final ecological status assessments of the lakes are obtained (Tab.5). For five lakes, the comparison with the type-specific reference assemblages and the type-specific diversity of reference leads to the same assessment of the ecological quality (or almost the same in the case of the Röddelinsee).

In the case of the Stolpsee, both assessments result in two completely different ecological status assignments. The assessment based on faunal assemblage leads to the poor status, while the assessment based on diversity proposes a good status. It clearly appears than the assessment of the ecological quality of Stolpsee is underestimated by the assessment using the faunal reference assemblage of type II, because this does not seem to be the correct faunal reference assemblage for Stolpsee. This confirms the prior conclusion that probably Stolpsee is not affiliated to type II, but with an extra type, and highlights once again the difficulty and the importance to identify correctly the type affiliation of each lake. This also underlines the limits of the approach based only on comparison with type-specific reference conditions proposed by the WFD.

Table 5: Ecological status of the 10 studied lakes based on both criteria used. Doubtful assessment due to doubtful type affiliation into brackets.

		High	Good	Moderate	Poor	Bad
Type I	**Stechlinsee**	**X**				
	Röddelinsee			**X**		
	Sacrower See				**X**	
Type II	**Gr. Wummsee**	**X**				
	Parsteiner See		**X**			
	Stolpsee		**(X)**			
Type III	**Beetzsee**				**X**	
	Breitlingsee					**X**
	Mellensee					**X**
	Plauer See				**X**	

4. Discussion

The final aim of the described project is to create a biotypology of 30 lakes from Brandenburg. Using the first results based on the study of 10 of them, our purpose was to test the approach proposed by the WFD to assess the ecological status of lakes using benthic macroinvertebrate assemblages. As the results reported here are only based on a part of the total data obtained during the project, the type-specific reference assemblages and diversities described here are not definitive, and the conclusions have to be tested again using the complete data set.
Finally, the ecological assessment of 5 of the 10 lakes studied could be successfully completed, strictly applying the recommendations of the WFD. Thus, a first conclusion can be that generally the lake classification approach suggested in the WFD is well working. For the five other lakes, we also obtained a first assessment of their ecological status, but individual case-studies revealed the limits of the WFD approach. Especially, two points need a further discussion.

First, the use of the system A appears to be inadequate in order to reach a precise typology related to specific biological characteristics on the national level. The cases of Stolpsee and Sacrower See highlighted this point. For example, the four variables imposed in system A are not sufficient to differentiate between the natural evolution of lakes and anthropogenic disturbances. Consequently some errors in identifying the type-specific reference lakes may occur (case of Sacrower See). It is then advisable to discern, for each lake, the origin of its eutrophication (natural or anthropogenic). Some kinds of anthropogenic influences (i.e. power plants, barge navigation, neozoa invasion, modification of shore structure) other than eutrophication, but which impact the faunal assemblages, must also be checked.

An other example is the imprecision of the variable "Geology". The water calcium content generally increases with the level of eutrophication of the lake (Tab.1), especially in lakes located in urbanised areas where construction works always increase the input of calcium from the catchment area. As a consequence, it is not possible in such regions to identify the natural level of water calcium and finally, in some case, to define the true geological affiliation of the lake. Thus, the use of the variable "Geology" in system A has to be modified.

Therefore, from our experience, system A is only useful to make a rough typology. System B is more appropriate, but even the list of the facultative factors has to be completed in order to cover all the types potentially met in Europe and to guarantee a relation with the biological typology. E.g., the connection of a lake to running waters, which influences the benthic assemblages by the drift of potamophilous species (case of Stolpsee), appears to be lacking.

The second point concerns the assessment of the level of degradation of lakes. Conceptually, as the comparison is based on reference assemblages, the both steps 'describing reference conditions for each lake type' and 'identifying the type of each lake' are absolute prerequisites for the assessment of the ecological status. Consequently, if no lake type can be assigned to a given lake, then its ecological status cannot be assessed. It is then not only the problem to find undisturbed lakes of reference or to reconstruct the invertebrate assemblages of reference using predictive models or palaeological methods but also, as shown by the case of Stolpsee, to recognise the accurate type affiliation of each lake. Probably for many heavily degraded lakes this task is not so easy to perform, so that they will remain unclassifiable. It might be thought that for lakes of poor and bad status this problem is not so important, because they will be restored anyway. But this does not apply for lakes with good to moderate status. Lakes of good to moderate ecological quality have to be carefully and correctly assessed, as the decision of their restoration (moderate status) or not (good status) will depend from the precision of the assessment of their ecological status.

To overcome this problem, we suggest an alternative and complementary approach. The WFD approach assumes that the degradation of the ecological conditions results in the disappearance of reference species. However, lake degradation is also accompanied by the colonisation by disturbance insensitive species, including a significant proportion of species independent of the type. In case type-specific reference lakes are lacking and it is impossible to establish benthic reference assemblages using predictive models or palaeological methods, a list of disturbance insensitive indicator species, which can statistically be derived from the databases, should be useful. This approach differs basically as it aims to establish lists of disturbance indicator species and their related abundances for each status levels and not for the type-specific reference lakes. Then, especially to discern between good to moderate status such a list of disturbance insensitive indicator species independent to the type should be really efficient. We assume that such an approach should contribute to solve the thorny problem of the precise identification of limits between status, as expressed during the SWAP conference.

References

Benzecri, J.P., 1983. L'analyse de l'inertie intra-classe par l'analyse d'un tableau de correspondances. *Cah. de l'An. des Données*, 8: 351-358.

Böhmer, J. and Baier, B., 2001. *Vorschrift zur standardisierten, semiquantitativen Makrozoobenthosprobenahme in Seen > 50 ha für die ökologische Bewertung nach Wasserrahmenrichtlinie.* Bericht im Auftrag der Länderarbeitsgemeinschaft Wasser, 6 p.

Chessel, D. and Doledec, S., 1993. *A.D.E. Version 3.6 : Hypercard Stacks & Programs. Library for the Analysis of Environmental data.* URA CNRS 1451, Université Lyon 1. User's manual, 750p.

Fisher, R.A., Corbet, A.S. and Williams, C.B., 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *J. Anim. Ecol.*, 12: 42-58.

Hurlbert, S.H., 1971. The nonconcept of species diversity : a critique and alternative parameters. *Ecology*, 52(4): 577-586.

Lenat, D.R., 1983. Chironomid Taxa Richness: natural variation and use in pollution assessment. *Freshwat. Invertebr. Biol.*, 2(4): 192-198.

Pinder, L.C.V. and Reiss, F., 1983. The larvae of Chironominae (Diptera: Chironomidae) of the Holarctic region - Keys and diagnoses. In: Wiederholm, T. (Ed.) *Chironomidae of the Holarctic region - Keys and diagnoses. Part 1 : Larvae.* Ent. Scand. Suppl., 19 : 1-457.

Acknowledgements

The project has been funded by the Landesumweltamt Brandenburg. We thanks the project working team consisting of Mario Brauns, Steffi Noack, Michaela Schönherr and Christian Polleichtner for their help during field sampling and the processing of the samples in the laboratory, including taxonomic identification.