An overview of methods potentially suitable for pond biodiversity assessment

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Abstract

This study provides a general overview of existing methods potentially suitable for assessing pond biodiversity. A bibliographic review allowed to evaluate the number of papers and consequently the interest of scientific investigation allocated (i) to different freshwater assessment objectives such as biodiversity, water quality or hydrological functions, and (ii) to biodiversity assessment for each of four waterbody types (ponds, wetlands, rivers & streams, lakes). The review was conducted using ISI Web of Science and browsing grey literature (reports from environment agencies and research institutes). Both methods designed for fundamental research and site management were taken into account.

The results emphasize that biological assessment methods for routine monitoring have been developed mostly for streams and rivers during the last two decades, and that lentic freshwater habitats have been rather neglected. Ponds, in particular, have been widely ignored despite of their significant contribution to regional biodiversity. Freshwater assessment methods mainly focus on water quality and hydrological aspects, while biodiversity is underrepresented.

Keywords: *small waterbodies, wetlands, species richness, monitoring, management*

Résumé

Revue de méthodes potentiellement utilisables pour l'évaluation de la biodiversité des étangs

L'objectif de cet article est de présenter une vue d'ensemble des méthodes potentiellement utilisables pour l'évaluation de la biodiversité des étangs. Une recherche bibliographique a été réalisée afin d'estimer le nombre de publications et, par conséquent, l'intérêt porté (i) aux objectifs poursuivis par les différentes méthodes d'évaluation, tels que la qualité de l'eau, les fonctions hydrologiques et la biodiversité, et (ii) à l'évaluation de la biodiversité de quatre types de milieux aquatiques (étangs, zones humides, eaux courantes, lacs). Des rapports d'études provenant d'agences environnementales et d'instituts de recherche (littérature grise) ont également été pris en considération. Nous nous sommes intéressés autant aux méthodes destinées à la recherche fondamentale qu'à celles destinées aux gestionnaires des sites.

Les résultats montrent, que des méthodes consacrées à l'évaluation routinière de la qualité biologique ont été principalement développées pour les eaux courantes, et que les eaux stagnantes n'ont pas bénéficié d'autant d'intérêt. Plus particulièrement les mares et étangs ont été largement ignorés en dépit de leur contribution significative à la biodiversité régionale. Les méthodes d'évaluation s'intéressent principalement à la qualité de l'eau et aux aspects hydrologiques; à l'inverse elles se préoccupent moins de la biodiversité.

Mots-clés: *petits plans d'eau, mares, zones humides, richesse spécifique, monitoring, gestion*

Introduction

Until recent years, freshwater ecosystem assessment has focused primarily on pollution control (Resh and Jackson 1993; Verdonschot 2000). The EC Water Framework Directive (WFD: European Commission 2000) and its concept of *good ecological status* calls now for a shift from a classical biogeochemical approach to an ecological approach and requires advanced assessment techniques (Wasson et al. 2003). In addition, independently of the WFD, and according to the goals of the U. N. Convention on Biological Diversity (1992), the EC Environmental Action Programme (European Commission 2002) aims to stop the loss of biodiversity by 2010. Given this framework, and in order to prioritize areas for

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conservation, biologists and managers need accurate information on species diversity. It has been shown (Oertli et al. 2000; Williams et al. 2003) that ponds, compared to rivers and streams, contribute most to regional biodiversity. Yet methods to evaluate pond biodiversity are rare. As a matter of fact, the attention during the last decades has mainly been focused on rivers and streams, illustrated for example by a considerable number of biological assessment methods (e.g. AFNOR 1992; Wright 1995; Boon et al. 1997; Wright et al. 1998; Karr and Chu 2000; Oberdorff et al. 2002; AFNOR 2003; Hering et al. 2003). Regarding these facts, it seems that ponds have been rather ignored, even in the recent WFD they are not explicitly mentioned. The aim of this paper is therefore to provide a general overview of freshwater biodiversity assessment methods potentially suitable to ponds in order to summarize useful information for the development of future pond assessment programs.

Methods of the bibliographic study

To begin with, a quantitative search using Science Citation Index Expanded (ISI Web of Science, Institute for Scientific Information) was carried out in March 2004 to evaluate the number of papers on the subject of biodiversity assessment of four different waterbody types: *ponds, wetlands, rivers & streams and lakes.*
Secondly, to gather potentially suitable methods for pond biodiversity assessment, an extensive literature survey was conducted on SCI Expanded searching with the following keywords individually and in combinations: *pond, wetland, river, stream, lake, biodiversity, assessment, evaluation, health and method.* Additional papers were obtained by examining cited references and from browsing the web for relevant reports by environment agencies and research institutes (*grey literature*). Only documents relating to freshwater ecosystems (with particular emphasis on ponds and wetlands) were retained. For this overview, methods for fundamental research have been equally considered as those designed for site management.

Objectives of freshwater ecosystem assessment

An assessment is an integrated statement about a current situation and the factors that contribute to that situation (Innis et al. 2000). It can be focused on different objectives, such as water quality, ecosystem function, biodiversity or integrity. Our literature survey reflects the effort allocated to different assessment goals for several types of aquatic habitat (Fig. 1): only 12% of the papers focus on biodiversity, whereas 17% deal with functional aspects (e.g. sediment and nutrient retention, flood storage, water purification) and 71% with water quality.
Among the reviewed studies, the terms used to define the assessment objectives are diverse and sometimes confusing (eacosystem health, bioassessment, biological status, ecological status, biological integrity etc). Bioassessment, for example, does not necessarily equate with biodiversity assessment, but refers to a method using bioindicators. It is therefore important to clearly define the type of information a method provides. To facilitate the comprehension it might be convenient to use the terminology defined

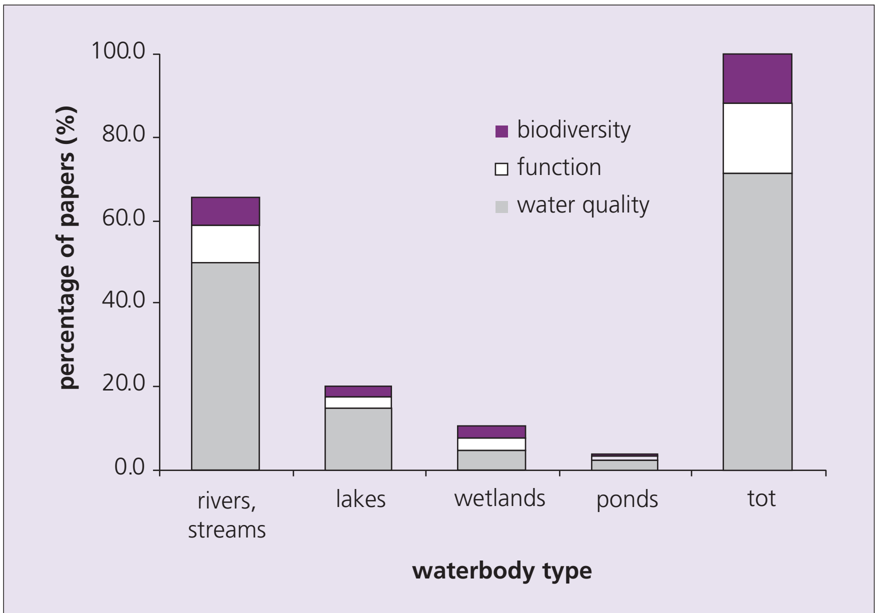

Fig. 1: Number of papers accorded to different assessment objectives (water quality, function, biodiversity) for four waterbody types (n = 1277). Browsed database: SCI Expanded (ISI Web of Science, March 2004).

in the WFD: "Ecological status" is an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters, classified in accordance with Annex V of the Water Framework Directive (European Commission 2000).

Regarding the different waterbody types being assessed, it can easily be seen (Fig. 1) that running waters receive the most attention and that ponds, at the opposite, are poorly documented.

Measurement of biodiversity

According to the Convention on Biological Diversity (1992), biological diversity means “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”. For the present overview, biodiversity is expressed in terms of species richness, which has become the common currency of much of the study of biodiversity assessment (Gaston and Spicer 2004). Two types of species richness metrics can be distinguished among the reviewed methods that focused on pond biodiversity: (i) the observed species richness (measured value), and (ii) the “real” species richness (estimated from the measured value). The observed species richness is the number of species observed during field investigations. As far as sampling is concerned, some authors highlight the fact that species richness recorded is vulnerable to variation in sampling effort (Lande et al. 2000; Magurran 2003) and to effects of abundance (Gotelli and Colwell 2001). To overcome these problems, i.e. to compensate for sampling bias, the use of “real” richness is recommended. To estimate “real” species richness from observed species richness, three main approaches are commonly used (see Magurran 2003): (i) extrapolations of species accumulation curves, (ii) fitting of species-abundance distributions and (iii) the use of non-parametric estimators. Non-parametric estimators, such as Chao (Chao 1984) and Jackknife (Burnham and Overton 1979), represent undoubtedly one of the most powerful tools (Colwell 1997; Foggo et al. 2003), as they are not based on a species abundance model that has been previously fitted to the data (Magurran 2003). To compute species accumulation curves or richness estimators, software packages can be used (e.g. EstimateS: Colwell 1997; Ws2m.exe: Turner et al. 2000).

To assess the collected data, different methods are used in the reviewed papers. Once the species richness has been measured, it can be assessed by a comparison either with the richness of a set of other sites, or with the richness for an unimpaired reference site. The richness of this reference site can be calculated by means of predictive models based on the relation between species richness and environmental variables. This approach is also suggested in the WFD (European Commission 2000), as an alternative of hindcasting methods. For building those predictive models, the influence of environmental variables on species richness has to be evaluated. This can be achieved by a classical regression analysis (Gee et al. 1997; Biggs et al. 2000). A non-parametric alternative to this technique is provided by Generalized Linear Models (McCullagh and Nelder 1997) or Generalized Additive Models (Hastie and Tibshirani 1990), which are used in the PLOCH method (Oertli et al. 2005). The strength of the GAM models is their flexibility: the relationship between two variables can take any curved form and does not depend on the implicit shape of a standard parametric regression. Finally, a promising nonlinear approach, not yet applied to still waters, is the use of artificial neural networks (Lek and Guegan 1999; Giraudel and Lek 2001; Céréghino et al. 2003). All these analyses enable the baseline prediction of the species richness of a site that is to be assessed and the comparison of predicted values with observed ones.

Methods suitable to ponds

A list of methods used in still waters and potentially suitable for assessing pond biodiversity is given in Table 1. The reviewed papers measure diversity at one (or more) of three different spatial scales: (i) regional diversity, i.e. the overall diversity within a large region (landscape or biogeographic province), (ii) local diversity, i.e. the diversity in one ecosystem (e.g. pond or wetland), and (iii) point diversity (sample diversity), i.e. the diversity in a sample. It appears that all the methods in Table 1 measure local diversity, 22 % assess also point diversity, but only one method addresses regional diversity.

Concerning the selection of taxonomic groups, only a third of the methods use more than two groups (Table 1). Most of the methods use invertebrates because of their qualities as indicators, such as being representative of the assessed habitat, and having well understood taxonomy, life history and ecology (see New 1995). Nevertheless, besides their quality as bioindicators, the use of invertebrates as surrogate for the diversity of other taxonomic groups is questionable. Indeed, the relationship between the richness of invertebrates and the richness of the whole biotic community is not clearly established (Gee et al. 1997; Heino et al. 2003).

The choice of the taxonomic level is a trade-off between an increased information content and the cost of obtaining it. Even though family or genus level data could be effective for assessing overall quality

Table 1: Selected stillwater assessment methods potentially suitable to ponds. Only methods including measurement of biodiversity have been retained

Author (method)	Target habitat	Country	Objectives	Studied taxa	Taxonomic level	Sampler type	Nb of sites	Scale of diversity
Macan 1977	ponds	UK	Species monitoring	Macroinvertebrates Crustacea Amphibia	species species species	Pond net, 1mm mesh, artificial substrate	1	point, local
Foster et al. 1990	Arable fenland	UK (Wash)	Conservation value	Coleoptera	species	Pond net, 1mm mesh	157	local
Jeffries et al. 1991	Forestry ponds	UK (Scotland)	Conservation value	Macroinvertebrates Amphibia Macrophytes	species[#] species species	Pond net	42	local
Gee et al. 1997	Ponds	UK (Wales)	Biodiversity	Macroinvertebrates Macrophytes	species* species	Pond net, 300 µm mesh	51	local
Williams et al. 1998 (PSYM)	Ponds, canals	UK (England & Wales)	Ecological integrity	Macroinvertebrates	family Macrophytes	Pond net species	142	local
U. S. EPA 1998, 2002 (IBI)	Wetlands, running waters	USA	Water quality Ecosystem health	Macroinvertebrates Amphibia Fish Birds Algae Macrophytes	genus species species species species species	Pond net	-	
Painter 1999	Ditches	UK (Wicken Fen)	Biodiversity	Coleoptera Mollusca Odonata	species species species	Pond net, 0.5 mm mesh Pond net, 0.5 mm mesh Pond net, 0.5 mm mesh	19	local
Biggs et al. 2000 (PSYM)	Ponds, small lakes	UK (England & Wales)	Ecological quality	Macroinvertebrates Macrophytes	family species	Pond net	313	local
BIOMAN 2000	Shallow lakes	B, DK, NL, E	Biodiversity	Bacterioplankton Protists Zooplankton Macroinvertebrates Fish Macrophytes	species species species[##] species species species	Core sampler Core sampler 64 µm mesh. Pond net, 500 µm mesh Gill nets, fyke nets	96	point, local
Jeppesen et al. 2000	Shallow lakes	DK	Biodiversity	Zooplankton Phytoplankton Fish Macrophytes	species species species species	80 µm mesh net Gill nets	71	local
Linton and Goulder 2000	Ponds	UK (East Yorkshire)	Conservation value	Macrophytes	species		57	local
Oertli et al. 2000, 2005 (PLOCH)	Ponds, small lakes	CH	Biodiversity	Odonata (adults) Gasteropoda Coleoptera Amphibia Macrophytes	species species species species species	 Pond net, 0.5 mm mesh Pond net, 0.5 mm mesh	80	point, local
Hawkins et al. 2001	Wetlands, mountain lakes	USA (Utah)	Biological integrity	Macroinvertebrates	genus	Hess-type sampler, 0.5 mm mesh	47	local
Sahlen and Ekestubbe	Forest lakes	S	Biodiversity	Odonata (larvae)	species	Pond net, 1.5 mm mesh	74	local

2001								
Wood et al. 2001	Industrial ponds	UK (Yorkshire)	Conservation value	Macroinvertebrates	species	Pond net, 250 µm mesh, Ekman dredge	36	local
Gernes and Helgen 2002	Wetlands	USA (Minnesota)	Wetland health	Macroinvertebrates Macrophytes	genus species	Pond net, 600 µm mesh, activity traps	44	local
Merritt et al. 2002	River oxbows	USA (Florida)	Bioassessment	Macroinvertebrates	subfamily / tribe	Pond net, 0.5 mm mesh	10	local
Vinson et al. 2002	Wetlands	USA (Utah)	Bioassessment Biological integrity	Macroinvertebrates	genus	Kicknet, 0.5 mm mesh	38	local
Wilcox et al. 2002	Wetlands	USA (Great Lakes)	Water quality Biological integrity	Macroinvertebrates Fish Macrophytes	genus species species	Funnel traps, blacklight traps Fyke nets	18	local
Briers and Biggs 2003	Ponds	UK (Oxfordshire)	Biodiversity	Macroinvertebrates	species	Pond net	130	local
Cottenie and De Meester 2003	Shallow ponds	B (De Maten)	Biodiversity	Cladocera	species	64 µm mesh net	35	local
Foggo et al. 2003	Ponds	UK (SW England)	Biodiversity	Macroinvertebrates (except Diptera)	species	Pond net, 1 mm mesh	3	point, local
Moss et al. 2003	Shallow lakes	EU	Ecological status	Macroinvertebrates Fish Plancton Macrophytes	species species species species	Stem tube, soft bottom corer Nylon nets, fyke nets 50 µm mesh net	66	local
Williams et al. 2003	Rivers, streams, ditches, ponds	UK (Oxfordshire)	Biodiversity	Macroinvertebrates Macrophytes	species** species	Pond net, 1mm mesh	80	point, local, regional
Angélibert et al. 2004	Ponds	F (Causses du Quercy)	Biodiversity	Macroinvertebrates Zooplankton Macrophytes	species species species	Pond net, 250 µm mesh 10 µm mesh net	3	point, local
Boix and Quintana 2004 (QAELS)	Ponds	E	Water quality	Microcrustacea Insecta	genus*** genus	Pond net, 250 µm mesh	-	
Chovanec et al. 2004	Floodplain areas	A (Danube floodplain)	Ecological status	Odonata	species		408	local
Hoffmann et al. 2004	Mountain ponds and lakes	USA	Monitoring	Macroinvertebrates Fish Amphibia Plankton Macrophytes	species species species species species	Pond net Various nets Plankton net, 64 µm mesh	-	
Grillas et al. 2004	Temporary ponds	F	Conservation	Macrocrustacea Macroinvertebrates Amphibia Macrophytes	species species species species	100 - 200 µm nets	-	
Karaus 2004	Parafluvial ponds	CH, I	Biodiversity	EPT Taxa	species	Kicknet, 0.25 mm mesh	119	point, local
Nicolet 2004	Temporary ponds	UK	Biodiversity	Macroinvertebrates	species	Pond net, 1mm mesh	71	local

#genus for Chironomidae, small Arthropoda, juvenile Hemiptera & juvenile Coleoptera
##except Rotifera: mainly genus
** family for Diptera*
*** genus for Diptera and Oligochaeta*
**** species for Daphnia and Moina*

(e.g. Balmford et al. 1996), species level datasets are more relevant and are used in most of the methods dealing with biodiversity.

Besides species richness, some methods also assess the *conservation value*, an important criterion for taking into account the degree of threat faced by the species (Eyre and Rushton 1989; Foster et al. 1989; Painter 1999; Linton and Goulder 2000; Oertli et al. 2002; Nicolet et al. 2004).

Regarding the range of existing sampling methods and sampler types, various techniques are used, including net sampling, core sampling or use of artificial substrate (Table 1). Mesh size for macroinvertebrate sampling, for example, varies from 0.25 to 1.5 mm; as differences in mesh size generate different retention probabilities of the invertebrates (see Bachelet 1990, Schlacher and Wooldridge 1996, Morin et al. 2004), standardization of the mesh size would be useful. The diversity of sampling methods indicates the importance of using standardized protocols and acknowledging the sampling biases (e.g. Muzzaffar and Colbo 2001). Some recent methods include standardized sampling (pond net sweeping for a given time): Williams et al. (1998), Biggs et al. (2000), Nicolet et al. (2004) and Oertli et al. (2005).

Methods used in wetlands

In addition to the methods potentially suitable to ponds (listed in Table 1), there are a certain number of assessment procedures available for wetlands, which have been developed for purposes such as hydrogeomorphic (Brinson et al. 1995) or biological assessment (U.S. EPA. 2002). Some of these procedures could also be suitable to ponds, as large wetlands often include one or more small lentic waterbodies. Many of these methods, mostly rapid assessments, rely on the use of metrics and provide a single score as an overall estimation of the ecological status of a site (e.g. Resh and Jackson 1993; Barbour et al. 1999; Miller and Gunsalus 1999; Mack 2001; Collins et al. 2003; Stapanian et al. 2004). Instead of standardized sampling they are often based on expert field investigations. Nevertheless, if rapid assessment methods are useful and attractive economic tools to assess anthropogenic impacts on aquatic ecosystems, they are not in all cases a substitute for biodiversity studies. Consequently, there is growing interest, illustrated for example by Alonso et al. (2002), in improving the accuracy of the rapid methods and adapting them for biodiversity assessment.

Conclusions

Ecological assessment methods for ponds are rare compared to methods designed for running waters. Even though a certain number of procedures are now available for measuring pond biodiversity, there is a need to strengthen the development of pond-specific methods for fundamental research on one hand, and for site managers on the other hand (rapid assessments). Concerning the estimation of species richness, the use of non-parametric techniques might be a powerful tool in reducing sampling bias.

Often a restricted number of taxonomic groups is used as a surrogate for diversity of the whole biotic community. Nevertheless, further studies need to be carried out in this field of species richness indicator taxa and flagship species to validate this approach (see for example Andelman and Fagan 2000). Taxa richness is often the unique metric used for the assessment of biodiversity; however, future methods should also take into account the species's degree of rarity (conservation value). Regarding the scale of measured biodiversity, most methods specifically address local or point biodiversity; it should now be evaluated how these methods could be designed to assess also regional biodiversity. Finally, according to Magurran's textbook on measuring biodiversity (2003), standardization should be recognized as a main element of any assessment method.

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