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Comparative assessment of scoring methods to evaluate the conservation value of pond and small lake biodiversity

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ABSTRACT

1. Fresh waters are among the most endangered ecosystems in the world. Practical tools to measure their biodiversity value are needed for their effective conservation. Besides species richness, other aspects of biodiversity, including the threat level of species also need to be considered. Currently, existing scoring methods for assessing the conservation value of freshwater fauna and flora assemblages are varied, and guidelines to select an appropriate method are lacking.
2. In this paper, it is hypothesized that scores to assess the conservation value of assemblages can vary markedly according to the type of method used. To test this, four types of scoring methods were applied differing in the weight given to Red List categories and in the expression of the score, i.e. either using mean per species or the assemblage as a whole, on sets of dragonfly and macrophyte data collected from varied types of small lakes and ponds in three different countries (France, Switzerland and South Africa).
3. The comparison of the different types of methods showed that the type of method used had a marked impact on the assessment of the conservation value of a water body: the expression per species or per assemblage as the weight given to Red List categories changed the value of a given water body.
4. Overall, results also confirmed that the different types of methods could be applicable in different geographical areas and types of standing water bodies, independently of the original area where the method was developed.
5. Results illustrated that, besides the species richness assessment commonly used, calculating conservation value as a mean per species is useful because it provides additional information. Overall, using methods expressed as a mean per species and coupling the Red List with other criteria gave the best performance.

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KEY WORDS: freshwater ecosystems; Red List; species richness; dragonflies; macrophytes; biotope quality

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INTRODUCTION

Fresh waters are among the most threatened ecosystems worldwide (Ricciardi and Rasmussen, 1999; Millennium Ecosystem Assessment, 2005). This is particularly true for ponds and small lakes, which are threatened by habitat loss, excessive nutrient load, chemical pollution, climate change, and invasion by alien species (Brönmark and Hansson, 2002; EPCN, 2007). Ponds and small lakes are numerous across many landscapes (Downing *et al*., 2006). They form networks essential to the meta-populations of many species and provide important ecological, social, and economic services such as wildlife habitat, livestock watering, fish production or recreational activities (Jeffries, 2005; EPCN, 2007). At the regional scale, they collectively support diverse, and in some cases unique biodiversity, often richer than that in running waters or large lakes (Williams *et al*., 2004; Biggs *et al*., 2005; Angelibert *et al*., 2006).

The conservation of biodiversity faces limited resources in time, funding and personnel (Kati *et al*., 2004) and needs effective, practical tools for measuring the conservation value of biodiversity. In ecology, one of the most commonly used measures of biodiversity is species richness (Magurran, 2004; Fleishman *et al*., 2006). However, measures based on species richness alone have the disadvantage of not taking into account species composition and therefore the level of threat to, or endemism among, the species present in a community.

Standardized scoring methods have been developed for the assessment of the conservation value of fresh waters worldwide. These use different combinations of physical and/or biological criteria (Boon and Pringle, 2009). The most used biological criterion (see among the selection of representative scoring methods in Table 1) is the IUCN Red List Categories (IUCN, 2001), hereafter referred to as the 'Red List'. Methods to assess the conservation value of fauna and flora assemblages, hereafter referred to as 'conservation value', are regionally diverse, with no consensus on a unified strategy. For example, all the existing scoring methods described in Table 1 have been developed for specific countries and have rarely been tested in other geographical areas.

One important difference among existing scoring methods that assess the conservation value is the weight they give to the Red List. Some methods are based exclusively on the Red List. For example the species quality score (SQS), developed by Foster *et al*. (1989), is based solely on the Red List for water beetles in the UK. The SQS concept has since been applied to other taxa in a variety of freshwater systems, from lentic to lotic, in the UK (Painter, 1999; Nicolet *et al*., 2004; Williams *et al*., 2004), France (Oertli, 1995; Godreau *et al*., 1999), and Switzerland (Oertli *et al*., 2002). Other methods which use the Red List, but also other biological and/or physical criteria include, for example, the Community Conservation Index (CCI), the Swedish System Aqua, the Dragonfly Biotic Index (DBI), the Lake Assessment for Conservation system (LACON) and the System for Evaluating Rivers for Conservation (SERCON). The CCI is used in the UK to assess the conservation value of freshwater invertebrate communities (Chadd and Extence, 2004). System Aqua uses the Red List threat level, naturalness of the catchment and species richness to assess the conservation value of seven freshwater and terrestrial groups (Willen, 2009). The DBI, developed for South African freshwater systems, also uses the Red List in combination with other criteria, in this case the geographical extent of species and the sensitivity of species to habitat disturbance (Samways, 2008; Simaika and Samways, 2009a). The LACON system (Duker and Palmer, 2009) and the SERCON system (Boon *et al*., 1997; Boon, 2000; Boon *et al*., 2002), developed in the UK, use the Red List in combination with many other biological criteria, such as the naturalness of the species assemblages, as well as in combination with physical criteria, such as the naturalness of the flow regime. Some scoring methods do not make use of the Red List at all, and focus rather on ecosystem health applying a combination of geomorphological, hydrological and ecological criteria (Amoros *et al*., 2000), or biological indicators as, for example, the Index of Centres of Density (ICD) developed in the USA by Angermeier and Winston (1997), which uses the number of source populations in an area to assess the conservation value of fish assemblages. Another method, independent of the Red List, has been developed in France for terrestrial plants, assessing the conservation value based on a combination of local rarity, regional rarity, and habitat vulnerability criteria (Gauthier *et al*., 2010).

Scoring methods to assess the conservation value of freshwater assemblages are expressed at different levels, either (i) the assemblage ('per assemblage'), or (ii) the species ('per species'), often a statistical

Table 1. Main characteristics of a selection of scoring methods used for the assessment of the conservation value of freshwater assemblages

Scoring method	Biological groups	Ecosystem	Spatial scale	Geographic location	Criteria	Principle of calculation	Expressed per species or per assemblage	Authors
Species Quality Score (SQS) and other similar methods (as C value)	Macrophytes Macroinvertebrates Odonata Amphibia	Standing or running waters	Ecosystem	UK Switzerland	- Threat category on the Red List	Sum of species threat levels	Per assemblage	Foster *et al.*, 1989 then Davies *et al.*, 2008, Nicolet *et al.*, 2004, Oertli *et al.*, 2002, Painter, 1999
Species Rarity Index (SRI) and other similar methods (as Csp value)	Macrophytes Macroinvertebrates Odonata Amphibia	Standing or running waters	Ecosystem	UK Switzerland	- Threat category on the Red List	Sum of species threat levels averaged by the number of species	Per species	Davies *et al.*, 2008, Nicolet *et al.*, 2004, Oertli *et al.*, 2002
Community Conservation Index (CCI)	Invertebrates	Standing or running waters	Ecosystem	Great Britain	- Threat level - Species richness	For the threat level, sum of species threat levels averaged by the number of species multiplied by a community score	Per species	Chadd and Extence, 2004
System Aqua	Macrophytes Macroinvertebrates Crayfish & Fish Amphibia Birds Mammals	Standing or running waters	Ecosystem or catchment	Sweden	- Naturalness - Threat category on the Red List - Species richness	For the threat level, sum of (i) a score depending on the maximal species threat level with (ii) the weighted sum of the number of species from other threat levels	Per assemblage	Willen, 2009
Dragonfly Biotic Index (DBI)	Odonata	Standing or running waters	Ecosystem	South Africa	- Species distribution - Threat category on the Red List - Species sensitivity to habitat change	Sum of the total per species of the three sub-indices averaged by the number of species	Per species	Samways, 2008, Simaika and Samways, 2009a
LACON	Macrophytes	Standing waters	Ecosystem	UK	- Species richness - Rarity (incl. threat category on the Red List) - Naturalness	None	Per assemblage	Duker and Palmer, 2009

(*Continues*)

Table 1. (Continued)

Scoring method	Biological groups	Ecosystem	Spatial scale	Geographic location	Criteria	Principle of calculation	Expressed per species or per assemblage	Authors
SERCON	Macrophytes Macroinvertebrates Fish Breeding birds	Running waters	Ecosystem	UK	- Population size - Species richness - Rarity (incl. threat category on the Red List) - Naturalness - Population size	None	Per assemblage	Boon *et al.*, 1997, Boon *et al.*, 2002
Index of Centres of Density (ICD)	Fish	Running waters	Site of an ecosystem	USA	- Population density	Sum of the ratio of the density of each species at each site to the sum of densities of the species over all sites averaged by the number of species	Per species	Angermeier and Winston, 1997

mean of the species belonging to the assemblage (Table 1). For example the SQS is expressed per assemblage, as it consists of the sum of the threat levels of all species belonging to the assemblage. An adaptation of the SQS, the Species Rarity Index (SRI) is, in contrast, expressed per species, and consists of the sum of the threat levels of all species belonging to the assemblage (i.e. the SQS) averaged by the number of species.

These many different types of methods can be confusing for nature conservation managers and environmental consultants, and could potentially lead to different management recommendations. The main aim here is therefore to clarify the differences between the types of methods in order to help the choice of method best tailored to any particular situation.

Our central hypothesis is that assessment of the conservation value of pond and small lake assemblages differs markedly depending on the type of method used, i.e. according to the weight given to the Red List and the expression of the score, whether using a mean per species or the assemblage as a whole. This hypothesis was tested by (i) analysing the differences between the conservation values given by different types of methods for the same assemblages (macrophytes or dragonflies) in order to identify potential redundancy or complementarity, and (ii) identifying the potential of different types of methods to provide additional information over species richness. Moreover, in order to clarify further the differences between the types of methods, some were tested to see if they could provide an additional tool to species richness estimates for evaluating biotope quality.

Another objective of this study was to confirm the applicability of a given method in different geographical areas and for different types of water bodies, independently of the original area and water bodies for which the method was developed.

MATERIAL AND METHODS

Biodiversity data sets

Water bodies from three different geographical areas were selected, two areas in Europe (France and Switzerland) and one in Africa (South Africa) (Figure 1, Table 2). In France (Figure 1(A)), 78 ponds located in a dense network of an area of 1000 km^2 (the Dombes region, north east from

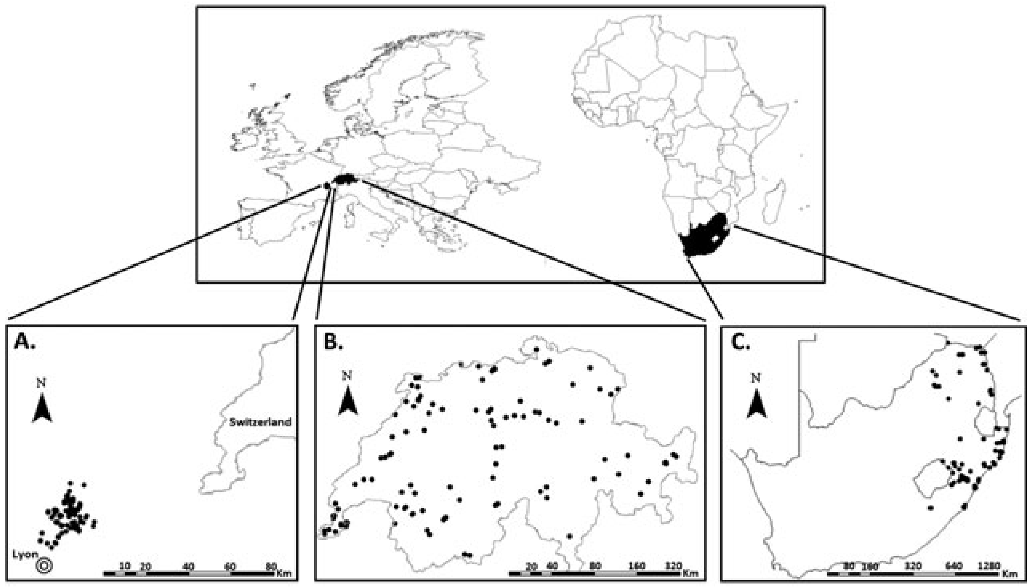

Figure 1. Location of the three study areas in Europe and Africa and location of the 623 sites studied: (A) in Dombes region of France, (B) in Switzerland, and (C) in South Africa.

Lyon), were studied during a project aiming at assessing the ecological value of fish ponds (Vallod *et al*., 2011; Arthaud *et al*.,). In Switzerland (Figure 1(B)), 90 ponds and small lakes scattered throughout the country were studied in the context of various projects (Oertli *et al*., 2002; Indermuehle *et al*., 2010; Menetrey *et al*., 2010). In South Africa (Figure 1(C)), 116 ponds and reservoirs scattered throughout the eastern part of the country were studied. The data consisted of systematic records from museum and private collections and sightings (from 1901 to present) (Simaika and Samways, 2009b).

Adult dragonflies (Odonata) and macrophytes were studied using presence/absence data. These two groups were chosen because data on adult dragonflies were available for all water bodies in the three countries, and data were available on macrophytes for all water bodies in Switzerland and for about two-thirds of the water bodies in France (55 of the 78 ponds).

Scoring methods for conservation value

The conservation value of dragonfly and macrophyte assemblages of small water bodies was assessed with four different types of methods distinguished by the weight given to the Red List and their expression, whether per species or per assemblage (see Introduction).

Scoring methods based exclusively on the Red List and expressed per assemblage

The first type of method was based exclusively on the Red List and expressed per assemblage. Two examples are used here: the C value (Oertli *et al*., 2002) and the rarity component of the Swedish System Aqua (Willen, 2009).

Table 2. Description of the three biodiversity data sets: France, Switzerland and South Africa

	France	Switzerland	South Africa
Number of ponds studied	76	90	116
Median pond area (min-max) [m^2]	9580 (1840–86 500)	2270 (6–96 000)	640 (4–110 000)
Median pond depth [m]	0.65	1.15	0.8
Range of altitude [m. a.s.l]	265–310	210–2760	0–2300
Range of nutrient load	eutrophic to hypertrophic	oligotrophic to hypertrophic	mesotrophic to hypertrophic
Origin	artificial	artificial and natural	mostly artificial
Main uses	fish farming	nature conservation recreation gravel or clay extraction fish farming	watering points for game or domestic livestock irrigation fish farming recreational fishing

The C conservation value is an application (Oertli *et al*., 2002) equivalent to the SQS (Foster *et al*., 1989, 1992; Painter, 1999; Williams *et al*., 2004; Davies *et al*., 2008; Copp *et al*., 2010) which ranks species according to their degree of rarity on the national Red List in geometric progression, successively doubling from 1 (commonest species) to 32 (rarest). The conservation value per site of the species assemblage (C value) is the sum of the scores of all species present at the site.

The rarity component of System Aqua, hereafter named the 'Aqua method', consists of a weighted value ranging from 0 to 5 based on species' threat status on the national Red List (for the exact formula, see Willen, 2009).

Scoring method based exclusively on the Red List and expressed per species: the Csp value

The second type of method is based also exclusively on the Red List, but expressed per species. The example of the Csp value is used here. The Csp conservation value is an application (Oertli *et al*., 2002) of the Species Rarity Index developed in the UK (Williams *et al*., 1998). As for the C value, species are ranked according to their degree of rarity on the national Red List following the same geometric progression as the C value. The mean conservation value per site per species (Csp value) is the C value divided by the number of species present in the site.

Scoring method coupling the Red List with other criteria and expressed per species: the Dragonfly Biotic Index

The third type of method couples the Red List with other criteria and is expressed per species. The example of the South African Dragonfly Biotic Index (DBI) (Samways, 2008; Simaika and Samways, 2009a) is used here.

The DBI is a composite index that consists of three sub-indices: species geographical distribution in the investigated area, threat status based on the national and global Red List, and species sensitivity to habitat disturbance (Simaika and Samways, 2009a). Disturbance, in the sense of the DBI sub-index, refers here to human disturbance, whether direct or indirect – for example, habitat degradation by invasion of alien species, cattle trampling, over-abstraction, and agricultural run-off. The DBI score per site, which originally consisted of the sum of the total per species of three sub-indices averaged by the total number of species and ranges from 0 to 3, was slightly modified in Switzerland and France. First, the mean of the three sub-indices was used instead of the sum, because of lack of data for one of the three sub-indices for some species. Then, the weightings of the sub-indices were replaced by a continuous gradient ranging from 0 to 1, so that the DBI score ranged from 0 to 1, rather than 0 to 3.

The need for information on species, geographical distribution in the investigated area and species sensitivity to habitat disturbance makes the DBI longer to compute compared with the methods based exclusively on the Red List. However, once the DBI is calculated, it is, for practical purposes, virtually permanent (Samways, 2008). The DBI allows the classification of species of Least Concern (LC), and so a more precise classification of sites with only LC species than other methods based exclusively on the Red List.

Scoring method independent of the Red List and expressed per species: the nested ranking method

The fourth type of method includes those methods that are independent of the Red List, and expressed per species. The example of the French 'nested ranking system', developed by Gauthier *et al.* (2010), is used here. This method is based on three criteria: regional rarity, local rarity and habitat vulnerability and classifies the species according to a hierarchical approach, where the regional rarity criterion is first order, the local rarity a nested criterion of second order and habitat vulnerability a criterion of third order. The first criterion, regional rarity, corresponds to the extent of the species' geographical distribution outside the study area, while the second criterion, local rarity, corresponds to the extent of the geographical distribution inside the study area. The third criterion provides information on the likelihood of habitat loss for a given species in the study region. The initial nested ranking method was slightly modified from weightings ranging from 0 to 5 to a continuous gradient of values rounded off to the first decimal place, and ranging from 0 to 1. To obtain a nested ranking per site, the same standardization procedure was applied as in the DBI, in which the total of all species ranks is divided by the total number of species.

As with the DBI, the need for information on species' geographical distribution and species' habitat vulnerability makes the nested ranking method longer to compute in comparison with the methods based exclusively on the Red List. This method also has in common with the DBI the ability to classify sites where all the species are of Least Concern more precisely than other methods based exclusively on the Red List. The nested ranking method does not consider changes in species' population sizes at a global scale, whereas the other methods indirectly incorporate this criterion through the Red List.

Data sources for the calculation of conservation values

The conservation values given by all scoring methods were calculated for adult dragonflies of South Africa and for adult dragonflies and macrophytes of France and Switzerland.

All scoring methods, except the nested ranking method, required the national Red List. Red Lists were available for both dragonflies and macrophytes in Switzerland (Gonseth and Monnerat, 2002; Moser *et al*., 2002; Auderset Joye *et al*., 2010) and for dragonflies in South Africa (Samways, 2006). In France, no Red List is currently available for dragonflies and macrophytes, so the Swiss Red Lists were used as a surrogate because of geographical proximity (see Figure 1(A)), species pool similarity (90% of the recorded French macrophyte and dragonfly species are present in Switzerland), and threat similarity (e.g. habitat loss, climate change, pollution).

The extent of species' geographical distribution within the study area was required for both DBI and the nested ranking method. In Switzerland, it was quantified for both biological groups by the number of grid cells of 20×20 km where a species is present (data from the Swiss Biological Records Center (CSCF), and the Swiss Floristic Records Center (CRSF)). In France, it was quantified using the frequency of occurrence of each species among the shallow lakes studied. In South Africa, the species' geographical distribution was scored from 0–3 with 0 for a species occurring throughout southern Africa and 3 for an endemic species on the basis of an unpublished dragonfly database (Simaika and Samways, 2009a).

The nested ranking method requires the quantification of the species' geographical distribution beyond the study area, i.e. in Europe for the Swiss data set, in Africa for the South African data set, and in France for the French data set, which consists only of a small portion of the country (see Figure 1(A)). For the dragonflies of Switzerland, it was quantified based on the presence of species in $500\,\text{km} \times 500\,\text{km}$ grid cells in Europe (data from Dijkstra and Lewington, 2006). For the macrophytes of Switzerland, it was not quantified because of lack of information. For both dragonflies and macrophytes of France, the geographical distribution outside the study area was quantified by the number of counties of France currently occupied by a species (Grand and Boudot, 2006; Le réseau des Botanistes Francophones, 2010). For the dragonflies of South Africa, it was quantified by the number of African countries where a species occurred (Dijkstra *et al*., 2011).

Information about habitat vulnerability or species sensitivity to habitat disturbance was required for both the DBI and the nested ranking method. In France and Switzerland, it was quantified for dragonflies on the basis of the affinity of each species for 20 types of freshwater habitats (Dommanget (1998) adapted by C. Deliry, available in Rosset and Oertli (2011)) and for macrophytes on the basis of the presence of each species in 52 types of aquatic communities (Rodwell, 2000). For dragonflies of South Africa, categories of species' sensitivity to habitat disturbance were distinguished on the basis of species' sensitivity to habitat change due to alien species and of species occurrence in disturbed water bodies according to the South African dragonfly database (Samways, 2008; Simaika and Samways, 2009a; Samways and Simaika, unpublished detailed database).

The way that the different sub-indices of each scoring method are calculated may vary depending on the data available in a particular study area for each biological group. Such variability does not strongly affect the conclusions of the present paper, because it compares the conservation values given by the different scoring methods for a particular group in a particular study area and not among the biological groups or among the study areas.

Statistical analyses

Differences and similarities among the conservation values calculated with the four types of scoring methods, as well as with species richness, were explored through Spearman-rank correlations using XL-STAT version 2011.1.05. In order to clarify further the differences among methods, their ability to measure biotope quality (i.e. the quality of pond habitats and pond surroundings) was assessed according to the method used by Barbour *et al*. (1996), US EPA (1998) and Hering *et al*. (2006). These authors evaluated the fresh waters of North America and Europe in the context of the Clean

Water Act and the Water Framework Directive, respectively. The principle of this method is to compare the number of sites classified as having very high/very low biotope quality by each type of scoring method with the number of sites classified as very high/very low biotope quality according to an independent assessment. This method was applied to the Swiss and French data sets. The independent assessment of the quality of 18 of the Swiss ponds was based on seven biological and environmental criteria confirmed by expert opinion (Menetrey *et al.*, 2010). The independent assessment of the quality of 25 of the French ponds was based on expert opinion and on two criteria specific to these ponds, i.e. fish-farming practices and ecosystem equilibrium (Vallod *et al.*, unpublished data). Ponds with conservation values above the 25th percentile of reference high quality sites were classified as 'very high biotope quality' sites, and ponds with conservation values under the 75th percentile of low quality sites were defined as 'very low biotope quality' sites.

RESULTS

Comparing the conservation values derived from the different types of scoring methods

Most of the conservation values of adult dragonfly and macrophyte assemblages were significantly correlated among each other (exceptions described below), but at different strengths (minimum: 0.29; maximum: 0.99) (Table 3, Table 4). Overall, the correlations between the conservation values were moderate (mean Spearman ρ of 0.54 for adult dragonflies and 0.75 for macrophytes).

As expected, when considering the scoring methods based exclusively on the Red List (the C value, the Csp value and the Aqua method), the correlations between

Table 3. Correlations (Spearman's rank) between the conservation values of dragonfly assemblages from Switzerland (upper value), France (middle value) and South Africa (bottom value) indicated by the different types of methods. Significant correlations: ** $P < 0.01$, **** $P < 0.0001$. 'RL' corresponds to methods based exclusively on the Red List, 'RL + others' to methods coupling the Red List with other criteria, and 'others' to methods independent of the Red List. 'assembl.' corresponds to methods expressed per assemblage and 'sp.' to methods expressed per species

	RL, assembl. C	RL, assembl. Aqua	RL, sp. Csp	RL + others, sp. DBI
RL, assembl. Aqua	0.665**** 0.905**** 0.619****			
RL, sp. Csp	0.731**** 0.831**** 0.593****	0.915**** 0.963**** 0.991****		
RL + others, sp. DBI	0.205 0.794**** 0.369****	0.442**** 0.761**** 0.582****	0.538**** 0.731**** 0.585****	
others, sp. nested ranking	-0.023 0.616**** -0.073	0.187 0.513**** 0.053	0.294** 0.444**** 0.066	0.723**** 0.832**** 0.305**

Table 4. Correlations (Spearman's rank) between the conservation values of macrophyte assemblages from Switzerland (upper value) and France (bottom value) indicated by the different types of methods. Significant correlations: **** $P < 0.0001$. 'RL' corresponds to methods based exclusively on the Red List, 'RL + others' to methods coupling the Red List with other criteria, and 'others' to methods independent of the Red List. 'assembl.' corresponds to methods expressed per assemblage and 'sp.' to methods expressed per species

	RL, assembl. C	RL, assembl. Aqua	RL, sp. Csp	RL + others, sp. DBI
RL, assembl. Aqua	0.949**** 0.769****			
RL, sp. Csp	0.714**** 0.799****	0.865**** 0.714****		
RL + others, sp. DBI	0.470**** 0.773****	0.575**** 0.641****	0.708**** 0.839****	
others, sp. nested ranking	NA 0.789****	NA 0.703****	NA 0.805****	NA 0.913****

the scores were all high (0.59 < Spearman ρ < 0. 99). The macrophytes were the exception in the French data set with the strongest correlation (Spearman ρ = 0.91) occurring between the conservation value indicated by the method that coupled the Red List with other criteria (DBI), and the one obtained independently of the Red List (nested ranking method) (Table 4). The scoring method independent of the Red List, in this case the nested ranking method, produced scores that were the most weakly correlated with the others for adult dragonflies (–0.02 < Spearman ρ < 0.83). For adult dragonflies in the Swiss and African data sets, the correlations were particularly weak, with half of the correlations non-significant. However, for macrophytes, the method independent of the Red List produced scores more strongly correlated with the others (0.70 < Spearman ρ < 0.91). The scoring method that coupled the Red List with other criteria, in this case the DBI, produced scores showing intermediate correlations with the other conservation values (0.21 < Spearman ρ < 0.83 for dragonflies and 0.47 < Spearman ρ < 0.84 for macrophytes). For adult dragonflies of the Swiss data set, the conservation value obtained with this method was not significantly correlated with the C value.

Considering the way the conservation values are expressed (by assemblage or by species), the values expressed per species – in this case the Csp value, the DBI and the nested ranking method – were not, on average, more correlated among each other than with the other values expressed per assemblage, the C value and the Aqua (mean Spearman ρ of 0.50 versus 0.53 for adult dragonflies and of 0.71 versus 0.82 for macrophytes).

Relationship between the different types of conservation values and species richness

The different types of conservation values were mostly significantly correlated with species richness in the three study areas, but with different levels of strength (minimum: 0.20; maximum: 0.95) (Table 5). Overall, the strength of the correlations between the values given by the different types of methods and species richness was not particularly strong (mean Spearman ρ of 0.50). Two conservation values expressed per species were not significantly correlated with species richness in the Swiss and South African data set. These were (i) the DBI method which couples the Red List with other criteria and (ii) the nested ranking method, which is independent of the Red List.

The conservation values based exclusively on the Red List (the C value, the Csp value and the Aqua method) were correlated with species richness in a similar way to the other types of methods (the DBI and the nested ranking method).

The conservation values obtained through the two methods expressed per assemblage (the C value and the Aqua system) showed the highest correlations with species richness for both dragonflies and macrophytes in all study areas (0.86 < Spearman ρ < 0. 95 and 0.26 < Spearman ρ < 0. 75). All other significant correlations between conservation values and species richness were weaker (0.20 < Spearman ρ < 0.66).

Ability of the different types of conservation values for measuring biotope quality

For both the dragonflies and macrophytes datasets from Switzerland and France the conservation values indicated by the different scoring methods were able to detect biotope quality in 11–85% of cases (Table 6). Species richness was able to detect biotope quality in 53-84% of cases (average 71%) and was more powerful than any conservation value.

There were no differences in ability to measure biotope quality according to the weight given to the Red List. The conservation values based exclusively on the Red List (the C value, the Csp value and the Aqua method) did not perform

Table 5. Correlations (Spearman's rank) between the species richness and the conservation values indicated by the different scoring methods for dragonfly and macrophyte assemblages from France, Switzerland and South Africa. Significant correlations: ** $P < 0.01$, **** $P < 0.0001$. 'RL' corresponds to methods based exclusively on the Red List, 'RL + others' to methods coupling the Red List with other criteria, and 'others' to methods independent of the Red List. 'assembl.' corresponds to methods expressed per assemblage and 'sp.' to methods expressed per species

		France		Switzerland		South Africa
Type of method	Example	dragonflies	macrophytes	dragonflies	macrophytes	dragonflies
RL, assembl.	C	0.863****	0.949****	0.938****	0.871****	0.880****
RL, assembl.	Aqua	0.623****	0.745****	0.423****	0.697****	0.258**
RL, sp.	Csp	0.475****	0.616****	0.508****	0.320**	0.201**
RL + others, sp.	DBI	0.609****	0.611****	0.041	0.171	0.139
others, sp.	nested ranking	0.588****	0.660****	-0.080	-	-0.131

Table 6. Percentage of sites for which the biotope quality was correctly detected by the different conservation values and by the species richness for dragonflies and macrophytes from France and Switzerland (18 sites for France and 25 sites for Switzerland). 'RL' corresponds to methods based exclusively on the Red List, 'RL + others' to methods coupling the Red List with other criteria, and 'others' to methods independent of the Red List. 'assembl.' corresponds to methods expressed per assemblage and 'sp.' to methods expressed per species

		France		Switzerland	
Type of method	Example	dragonflies	macrophytes	dragonflies	macrophytes
RL, assembl.	C	49	60	49	72
RL, assembl.	Aqua	45	85	14	77
RL, sp.	Csp	30	55	14	56
RL + others, sp.	DBI	35	45	32	44
others, sp.	nested ranking	50	60	11	-
species richness	-	53	75	72	84

better or worse than the conservation value coupling the Red List with other criteria (the DBI), or the conservation value independent of the Red List (the nested ranking method).

When considering the way the conservation values are expressed (by assemblage or by species), the conservation values expressed per assemblage and previously demonstrated to be highly correlated with species richness (the C value and the system Aqua) were the most sensitive in detecting biotope quality (on average 57% and 55% cases, respectively).

DISCUSSION

Comparison of the different types of scoring methods

The weight given to the Red List by the different types of scoring methods had a marked impact on the assessment of the conservation value of a particular pond. The scoring methods based exclusively on the Red List gave strongly correlated conservation values. This situation was to be expected because these methods rely entirely on the same data source, the Red List, to assess the conservation value. The relationship of these scoring methods with other methods, either coupling the Red List with other criteria, or independent of the Red List, was distinctly weaker. In contrast, the way the conservation values are expressed (per assemblage or per species), in contrast, did not have any impact on the strength of the correlations between conservation values. The conservation values expressed per species were not more highly correlated with each other than with the conservation values expressed per assemblage.

Do the different types of scoring methods provide additional information over species richness?

Some of the types of scoring methods showed a potential to provide additional information over species richness, while others did not. The scores obtained through methods expressed per assemblage were most strongly correlated with species richness, and this was mostly the case in all study areas, and for both macrophytes and dragonflies. This high correlation can be explained by the fact that, as with methods expressed per assemblage, each species, whether Red Listed or not, increases the conservation value. Therefore, conservation values expressed per assemblage provide very little extra information over species richness. Calculation of this type of conservation value appears to be an unnecessary step in the assessment of the conservation value of water bodies.

In contrast, the conservation values expressed per species do provide additional information over species richness assessments. Indeed, conservation values expressed per species were weakly correlated or not correlated at all with species richness. Such weak correlations have already been demonstrated for the DBI in South African rivers (Simaika and Samways, 2011) and for the Csp value in Switzerland (Oertli *et al.*, 2002). These large differences between the conservation value and species richness confirm that measuring the conservation value of a site per species could provide additional information over measurement of species richness, while also revealing perspectives on species composition.

In summary, the way the conservation values are expressed (per assemblage or per species) has a marked impact on the strength of the correlation with species richness, and the conservation values expressed per assemblage brought no additional information over species richness. This high redundancy suggests that there is no need to use conservation values expressed per assemblage, but that using conservation values expressed per species is useful in assessing water bodies.

The added usefulness of using scoring methods assessing conservation values over species richness for measuring biotope quality

In this study, species richness alone was a better metric than any measure of conservation value for describing biotope quality. Although not as powerful as species richness, scores for conservation value expressed per assemblage were more powerful for assessing biotope quality than scores for conservation value expressed per species. Evidently, the good performance of methods expressed per assemblage is directly related to their strong correlation with species richness.

These results suggest that conservation values are only weakly related with biotope quality, and therefore, that a biotope of poor quality can, surprisingly, host communities of high value. Part of the explanation could lie in potential large differences in the autecology of rare species (e.g. contrasting habitat or water quality requirements). The fact that conservation value appeared to be a weak indicator of biotope quality, in contrast to species richness, is consistent with the previously demonstrated ecological significance of species richness, which is frequently highly related to abiotic stresses that affect freshwater ecosystems (Bornette *et al.*, 1998, 2001; Riis and Sand-Jensen, 2001; Hinden *et al.*, 2005).

Geographical and ecological limits to the applicability of the different types of scoring methods

The different scoring methods of conservation value investigated here were developed in specific countries (Switzerland, France, Sweden, South Africa and UK) and have not previously been tested in other geographical areas. The mechanics of the different types of scoring methods suggests that they can be readily transferred from the specific context of one country to another, as well as from one particular taxonomic group to another; this transferability is confirmed by the present study. The different methods were also tolerant of the particularities and constraints of each geographical species pool. The only limitation to worldwide applicability is the availability of information concerning the regional species pool of a particular area (e.g. Red Lists, geographical distribution, ecological information). The present investigation also showed that the different scoring methods can easily be transferred among different types of standing water bodies (e.g. small lakes, fish ponds, reservoirs).

Recommendations on assessing the conservation value of water-body biodiversity

The results of this study indicated that, when evaluating an ecosystem, two indices should be used. First, species richness should be used because, at ‘equal species interest’, sites with high species richness have a higher priority in terms of conservation than those with low species richness. In addition, species richness gave the best performance for measuring biotope quality. Second, a scoring method of conservation value should also be used so that, in cases (for example) of equal species richness, priority species can be highlighted. Among the four types of methods tested, the conservation values expressed per assemblage should not be used, not because of any lack of power, but because of redundancy with species richness. The three remaining types of scoring methods, all the ones expressed per species, provided additional information over that of species richness. They produced sets of conservation values (for dragonfly and macrophyte assemblages) that were moderately correlated with each other. This suggests that each provides different information about the conservation value of an ecosystem, reinforcing the need for recommendations concerning their use.

We therefore underline here some methodological differences which could help nature managers and environmental consultants tailor the choice of a type of conservation value(s) (Table 7). First, the scoring methods based only on the Red List are faster to calculate than the other methods that require additional criteria. Then, two types of conservation values (combining the Red List with other criteria and independent from the Red List) have a larger spread of values, when many species are of Least Concern (LC) status. This could have the advantage of classifying more precisely sites that have only LC species, and have the same conservation value when using methods based exclusively on the Red List. Finally, the conservation values independent of the Red List have the disadvantage of not taking into consideration continuing changes in species' population size at the regional scale. It assigns the same conservation value to a species currently rare but stable or in decline, as one currently rare but increasing in abundance (due to climate change for example). All the other types of scoring methods indirectly incorporate this aspect, which is taken into account in the Red List.

Table 7. Criteria which could help nature managers and environmental consultants in choosing among three different types of scoring methods for conservation value. The methods expressed per assemblage have been discarded because of their high redundancy with species richness (see Discussion for more details). 'RL' corresponds to methods based exclusively on the Red List, 'RL + others' to methods coupling the Red List with other criteria, and 'others' to methods independent of the Red List. 'assembl.' corresponds to methods expressed per assemblage and 'sp.' to methods expressed per species

	RL	**RL + others**	**others**
Example (method tested in the present study)	Csp value	DBI	nested ranking
Time to compute	short	long	long
Values spread on a large gradient (even when many species without RL status)	no	yes	yes
Calculation using knowledge on the trend in species' population size	yes	yes	no

In conclusion, the methods expressed per species and coupling the Red List with other criteria, for example the DBI, give the best performance. Where there are financial limitations for an assessment, the methods expressed per species and based exclusively on the Red List, even if performing less well, could be used because of their ease of calculation. The selection of a type of method also depends on the species information available (i.e. Red List status, geographical distribution, ecology). Where there is a lack of information on species' habitat vulnerability or species' sensitivity to habitat disturbance, the methods expressed per species and based exclusively on the Red List would be the only option. In the case of imprecise Red List assessments or absence of Red List assessments, the methods expressed per species and independent of the Red List would be preferred.

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