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# A new method to estimate aquatic invertebrate diversity in French shallow lakes and ponds

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ABSTRACT

Shallow lakes and ponds are valuable ecosystems for conservation management. Aquatic invertebrates constitute a large proportion of diversity in these ecosystems, but their assessment is potentially time consuming and requires great expertise. The use of indicator taxa to estimate invertebrate diversity may resolve part of these difficulties. These indicators are rarely identified or their reliability is uncertain, i.e. they are based on partial inventories, neglecting groups with high diversity. In this study, invertebrate richness was assessed from 46 sites in France in various altitudinal, climatic, geological, human-impacted, and hydro-morphological contexts. Invertebrate identification was performed as accurately as possible in all taxonomic groups. Several potential indicators of diversity based on five key criteria were tested: strong direct correlation, identification facilities, strong cross-taxon congruence, low complementarity of the sampled habitats, and ubiquity for selected indicators. Three approaches were proposed to define these indicator groups: (1) a single taxonomic group as indicator, (2) a combination of targeted groups, and (3) a holistic inventory at low taxonomic resolution as a classical rapid assessment method for freshwater ecosystems. Results show that it is not recommended to use only one indicator group. The choice of several targeted groups could be a good intermediate solution but is not without bias. The rapid assessment inventory proposed is the most valuable method, and allows the estimation of invertebrate richness with a quasi-perfect correlation.

## 1. Introduction

Pools and ponds are recognized as ecosystems housing mostly specific and high conservation value species (Collinson et al., 1995; Beebee, 1997; Linton and Goulder, 2000; Williams, 2004; Davies et al., 2008). Managers have limited tools and do not have the financial or technical capabilities to conduct comprehensive inventories when assessing the effectiveness of management practices on biodiversity, and the functioning of these ecosystems, (Williams et al., 2010; Pyke, 2005).

Since the Clean Water Act (CWA) by the United States Congress, guidelines for the rapid assessment of surface waters has been developed (Karr and Chu, 1999) and largely tested in streams and lakes, especially in Europe within the Water Framework Directive WFD (Birk et al., 2012). Ponds and small shallow lakes (< 50 ha) are not included in the WFD, so most European countries do not have standardized methods to assess these ecosystems (Oertli et al., 2005). The few existing methods (Biggs et al., 2000; Oertli et al., 2005; Angélibert et al., 2010) are (1) limited in geographic applicability to the UK or Switzerland, (2) not shaped to sample all ranges of surface area not covered by the WFD, and (3) not designed to collect quantitative data, necessary to calculate usual (as Shannon index, Shannon and Weaver, 1949) or functional indicators as biological or ecological traits (Usseglio-Polatera et al., 2000a; Culp et al., 2011).

Invertebrates occupy a central role in food chains, influencing energy flows and nutrient cycling (Cummins et al., 1989; Newman, 1991; Covich et al., 1999) and offer many possibilities for bioindication while representing a very important faunal richness (Rosenberg and Resh, 1993).

However, assessing the invertebrate fauna richness of a site is a real challenge because of difficulties in the identification of some taxa, e.g. sparse literature, sometimes little-known taxonomy, and time required to extract fauna samples. To overcome ecosystem complexity and estimate diversity, many ecologists have been forced to develop alternative methods to indicator taxa (Hilty and Merenlender, 2000). The choice of these groups is very pragmatic and usually based on protection status, public attractiveness, or presence of local experts (Chovanec, 1998; Angélibert et al., 2010). Nevertheless, it seems difficult to argue that these taxa are truly representative of global

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invertebrate richness. According to this approach, the Limnephilidae and Coenagrioniidae (Briers and Biggs, 2003), families or genera of Coleoptera (Sánchez-Fernández et al., 2006), Coleoptera species (Hassall et al., 2011), Odonata, Coleoptera and Gastropoda genera combination (Oertli et al., 2005), Odonata species (RhoMéO project – Agence de l'Eau Rhône-Méditerranée, 2011) were identified as good indicator species.

However, there are limitations to using these taxa: (1) their applicability is low in other ecoregions (Briers and Biggs, 2003), (2) they provide an incomplete picture of the real faunal richness, related to the identification of higher taxonomic levels or the exclusion of some very diversified groups such as Diptera (Keiper et al., 2002 Angélibert et al., 2004; Ferrington, 2007; Wagner et al., 2007), (3) there is difficulty in predicting global richness with accuracy because the indicators are too difficult to identify (for example genus Helophorus in Hassall et al., 2011) or are too little diversified, causing low amplitude responses (respectively 13 species of Limnephilidae and five species of Odonata in Briers and Biggs (2003)), (4) there is low utility for indicator groups in predicting biodiversity in aquatic ecosystems because of weak cross taxon congruence in aquatic ecosystems (Heino, 2010).

To develop monitoring tools to assess the health and biodiversity of these ecosystems in metropolitan France, the BIOME project (BIOindication des Mares et Etangs) was initiated, based on the study of invertebrate and macrophyte communities, considered as ecosystem engineers (Mitsch and Gosselink, 2007).

The objectives of the project are to develop (1) low-cost, reproducible and representative sampling methods and (2) national indicators to identify functional and biodiversity losses and gains for management practices and impact studies.

In this work, 46 sites has been selected considering all bias described above, to find a robust estimation of invertebrates richness while respecting rapid bioassessment criteria (Barbour et al., 1999). Results obtained in this work allowed to finalise optimisation of the sampling procedure.

Other results for macrophytes and invertebrates, conducted actually upon 240 sites, will be detailed in further papers.

## 2. Methods

### 2.1. Definition of surveyed groups

Macroinvertebrates were considered any taxa whose average size is greater than 0.5 mm and whose life cycle is several months, in order to obtain communities with good stability over time. These criteria therefore included water mites (Bartsch, 2007) whose average size is around 0.5 mm, but excludes large micro-crustaceans, which are often well-represented in these shallow waters.

### 2.2. Study sites

To account for the eco-regional impact, sites were selected in various contexts: altitudinal (from 5 m to 2200 m), geological (e.g. pH 5.5–8.4, alkalinity 0.26–17.7, $Ca^{2+} < 1–108\ mg/L^{-1}$), and climatic (Atlantic, Continental, Mediterranean and Alpine). For completeness of assessing the invertebrate richness, all macroinvertebrates were identified to the lowest taxonomic level allowed by the existing literature (usually the species, genus or species group). Sites represented various hydro-morphological and human-impacted contexts: (1) for hydrology, ombrotrophic to rheotrophic (sensu Gilvear and McInnes, 1994) and permanent or temporary ponds, (2) for area, 2–108 000 $m^2$, (3) for depth, 0.2–6 m, (4) for human impacts, reference conditions to sites impacted by invasive red swamp crayfish (*Procambarus clarkii*), pollution, and various impacted watersheds. Pressures (coverage of landscape usages, fish stocking, banks verticality…) has been defined by cartographic analyses, informations provided by managers or owners, and field observations.

### 2.3. Sampling and fauna identification

Invertebrates were sampled from an experimental method of rapid monitoring, adapted from IBEM sampling (Indermuehle et al., 2008). The sampling is based on a maximum of 12 samples in 14 potential habitats with a hand-net (rectangular frame 25 × 20 cm, mesh size 0.5 mm). These habitats were as follows: roots, eight macrophyte morphological types, three mineral or organic deposited habitats, and two optional habitats (open water and flagstone), which were sampled only under certain conditions (e.g. shadowed ponds and rock pools for open water). The number of realized samples depended on habitat presence and sampling repetitions were possible according to some cases of well-defined shapes. For each sample, the net was swept intensively in 1 $m^2$ during 10 s for each habitat, except for deposit or algal habitats, where 0.25 $m^2$ was sampled at 4 cm depth when possible.

Sampling was carried out from April to August to include phenology, from 2013 to 2016. All invertebrates were identified to the lowest possible taxonomic level according to the existing literature. All taxa were identified to species level when possible, except Diptera, Nematoda, and Scirtidae (levels varying in these groups: genera, subgenera, group of species or species).

A joint rapid inventory of macrophytes was also carried out using a method based on PSYM (Shelley, 2009) and XPT90-328 French standard (AFNOR, 2010). Macrophyte richness was included in tests to verify whether macrophytes can be used as indicator taxa and if their richness can be predicted by invertebrates.

### 2.4. Indicator groups

Three bioindication approaches were tested.

#### 2.4.1. Single-taxon

A single taxonomic group may be indicative of global diversity. This approach is widely used (e.g. Kerr et al., 2008; Campos et al., 2014) and has given very different results, especially in temperate regions where diversities are lower (Lund and Rahbek, 2002). In aquatic ecosystems, it seems inefficient, because taxa respond differently to environmental condition or pressure (Heino, 2010). Coenagrioniidae and Limnephilidae, highlighted by Briers and Biggs (2003) were not tested in this study because of insufficient diversity (less than five species per pond), thereby impairing an accurate estimation of global richness.

#### 2.4.2. Association of targeted taxa

This approach was based on a set of pragmatic criteria, described by Oertli et al. (2005). The study of several faunal groups can give the most accurate picture of overall faunal richness because they integrate different habitat conditions, trophic niches, etc. The taxa considered in the IBEM (Indice de Biodiversité des Étangs et des Mares, Indermuehle et al., 2008) were selected, including the identification levels and taxa specified by the method. This method is named the "IBEM-like" method because of different sampling methods, especially for Odonata, which is conducted with imagines in IBEM and larvae in IBEM-like. Several other combinations were tested, such as the "TOC method", which identifies Trichoptera, Odonata and Coleoptera at genera level.

#### 2.4.3. Holistic

All invertebrates were identified with a level of precision matching reasoned balance between ecological information and identification facilities (e.g. low-cost and reproducibility of the method), as part of a method for rapid assessment. This taxonomic resolution allows the use of biological and ecological traits adapted to water bodies and other indicators commonly used in aquatic ecology. This resolution corresponds to one adopted in the present research. All taxa were identified at genera level, except Corixidae (subfamilies), Diptera (families), Hydrachnoidea (superfamily), Oligochaeta and Hydrozoa (class), Bryozoa and Nematoda (phylum).

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