AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS
Aquatic Conserv: Mar. Freshw. Ecosyst. **13**: 323–330 (2003)
Published online 6 March 2003 in Wiley InterScience
(www.interscience.wiley.com). DOI: 10.1002/aqc.576

Indicator taxa for the conservation of pond invertebrate diversity

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ABSTRACT

1. Ponds are a valuable resource for the conservation of freshwater biodiversity, but are often extremely numerous in a given area, making assessment of the conservation value of individual sites potentially time consuming.
2. The use of indicator taxa, the species richness of which is representative of total site species richness, may provide one way to improve the efficiency of survey work. However, such indicators are poorly developed for freshwater systems.
3. A data set was used describing the occurrence of macroinvertebrate taxa in ponds in Oxfordshire, UK, to assess the extent to which variation in the species richness of selected taxa most consistently represented variation in all other taxa.
4. Coenagriidae (Odonata) and Limnephilidae (Trichoptera) reflected the variation in species richness of other taxa most consistently, with Coenagriidae showing the best overall performance as an indicator taxon.
5. For both suggested indicator taxa, selection of sites based solely on the presence of at least one species of indicator would represent over 95% of all species recorded across all sites.
6. Further investigation in different geographical regions is necessary to establish whether these relationships are consistent over a wider area.

KEY WORDS: indicator taxa; pond conservation; macroinvertebrates; Coenagriidae

INTRODUCTION

In many landscapes, ponds can be a valuable resource for the conservation of freshwater biodiversity, often containing specialized flora and fauna which are not represented in other habitats (e.g. Bratton, 1990; Williams *et al*., 1998). There are many criteria which may be used in the evaluation of the conservation interest of sites (Ratcliffe, 1977; Usher, 1986) but as with most other ecosystems, assessment of the

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Received 17 June 2002
Accepted 29 November 2002

conservation value of pond sites commonly begins with extensive surveys to determine the patterns of species richness and identity. Sites may be judged to be of conservation significance on the basis of one or more criteria, for example high species richness or the presence of taxa of particular conservation interest or rarity. The focus of the present paper is on the assessment of species richness patterns across sites.

Despite high rates of loss (Heath and Whitehead, 1992; Boothby *et al*., 1995) ponds are still found at high densities across the landscape in many areas (Rackham, 1986; Boothby and Hull, 1997; Williams *et al*., 1998) which makes assessment of the species richness of individual sites, even within a restricted geographical area (e.g. Pond Action, 1994a,b; Pond Life Project, 2000), time consuming and potentially costly. Limitations on the resources available for surveys of a large number of sites are common to most conservation organizations and hence there has been significant interest in the concept of indicator taxa whose species richness is representative of the total species richness of a site (Schall and Pianka, 1978; Beccaloni and Gaston, 1995; Gaston, 1996; Howard *et al*., 1998). Determination of the species richness of a representative subset of the entire community should result in significant savings in terms of time and resources necessary to assess the conservation value of sites. The potential for various groups to act as indicator taxa has been assessed for terrestrial systems, primarily in tropical areas where patterns of species richness are particularly poorly known, with varying degrees of success (Beccaloni and Gaston, 1995; Howard *et al*., 1998; Lawton *et al*., 1998).

In freshwater systems indicator taxa (mostly identified to family level) have been used extensively to monitor the status of freshwater habitats with respect to potential pollutants or nutrient enrichment (e.g. Savage, 1982; Rosenberg and Resh, 1992; Wright *et al*., 1993). Other systems, based on multiple critera, have also been developed to aid the conservation assessment of both lentic and lotic habitats (e.g. Palmer *et al*., 1992; Boon *et al*., 1997). However little attention has been paid to the development of indicator taxa for assessment of freshwater invertebrate biodiversity. Several macroinvertebrate groups have been suggested as indicator taxa (e.g. Coleoptera — Foster *et al*., 1989; Foster and Eyre, 1992; Odonata — Davis *et al*., 1987). In Britain, the richness of both of the above groups is used as a criterion for the selection of Sites of Special Scientific Interest (SSSIs) (Nature Conservancy Council, 1989). Despite this, few attempts have been made to establish formally whether the richness of the chosen groups is representative of the community as a whole (but see Jeffries, 1988). Here a data set describing invertebrate communities in ponds is used to assess the extent to which different taxa are effective indicators of the species richness of the entire invertebrate community.

METHODS

Data set used

The analyses are based on a data set of freshwater macroinvertebrate communities in 130 ponds in Oxfordshire, UK. This is derived from the Oxfordshire Pond Survey carried out between 1989 and 1990 by Pond Action (Table A3.8 in Pond Action, 1994b). A total of 256 species of macroinvertebrate was recorded from these sites. Further details of the sites and survey methodology are given in Pond Action (1994a,b). The data set covers approximately 5% of the total 2000–3000 ponds found within Oxfordshire (Pond Action, unpublished data).

Assessment of indicator status

Indicator taxa were assessed at the family level by calculating the number of species found in each family at each site. Potential indicators were restricted to families represented by at least four species in the data set in order that there was sufficient variation in taxon richness to reflect the variation in other groups (Table 1). Following other studies (e.g. Prendergast and Eversham, 1997; Howard *et al*., 1998) the extent to which the

Table 1. Potential indicator taxa and the total number of species recorded in Oxfordshire Pond Survey sites

Group	Family	Species richness
Coleoptera	Dytiscidae	46
	Elmidae	4
	Gyrinidae	4
	Haliplidae	14
	Hydraenidae	6
	Hydrophilidae	36
Gastropoda	Lymnaeidae	6
	Planorbidae	10
Hemiptera	Corixidae	20
	Gerridae	4
Hirudinea	Glossiphoniidae	5
Odonata	Coenagriidae	5
	Libellulidae	4
Trichoptera	Leptoceridae	5
	Limnephilidae	13
	Polycentropodidae	6

richness of one taxon was representative of all other taxa was assessed by calculating cross-taxon correlations of species richness (Pearson product moment correlation). This method is preferable to correlating the richness of an individual taxon with the overall species richness of a site. Speciose taxa contribute a larger proportion of the total site richness, resulting in an artefactual positive relationship between taxon species richness and the correlation with total species richness.

The mean and range of cross-taxon correlations was examined to assess which taxa reflected the variation in richness of other groups most consistently. Taxa with higher mean correlation coefficients and smaller deviation between the mean and minimum value (hereafter termed the lower range) were treated as good indicators. Further analysis of the variation in cross-taxon correlations between taxa (i.e. ANOVA) was not possible due to the non-independence of correlation coefficient values for each taxon (e.g. the correlation between Limnephilidae and Corixidae contributes to the calculations of means and ranges for both groups). Taxa represented by fewer than four species were combined into one group for the calculation of cross-taxon correlations.

The existence of a statistical correlation between species richness of taxa does not necessarily indicate the extent to which sites selected on the basis of indicator taxa effectively represent wholesale species richness across all sites. Therefore, the proportion of the total number of species present across all sites (256) that would be represented by basing site selection on the presence of different numbers of species of the indicator taxa was also calculated. While there is an inherent circularity in using the same data set to define and test potential indicator taxa, this procedure still provides useful information on the performance of different taxa as indicators of species richness for the sites concerned.

RESULTS

The means and ranges of cross-taxon correlations are shown in Figure 1. The families Coenagriidae (Odonata) and Limnephilidae (Trichoptera) both had cross-taxon correlations which were all highly significant ($P < 0.001$) suggesting that the variation in species richness of these groups is highly representative of the variation of all other groups. Coenagriidae had a slightly higher mean and smaller lower range of cross-taxon correlations than Limnephilidae. All other taxa had at least one cross-taxon

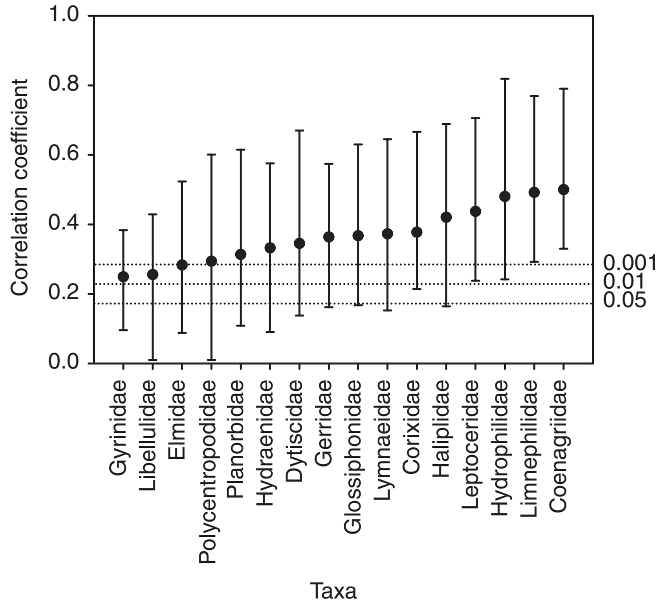

Figure 1. Mean and range of cross-taxon correlations for potential indicator taxa. Taxa are arranged in order of increasing mean cross-taxon correlation. The dotted lines indicate the values of the Pearson correlation coefficient at different levels of significance for $n = 130$.

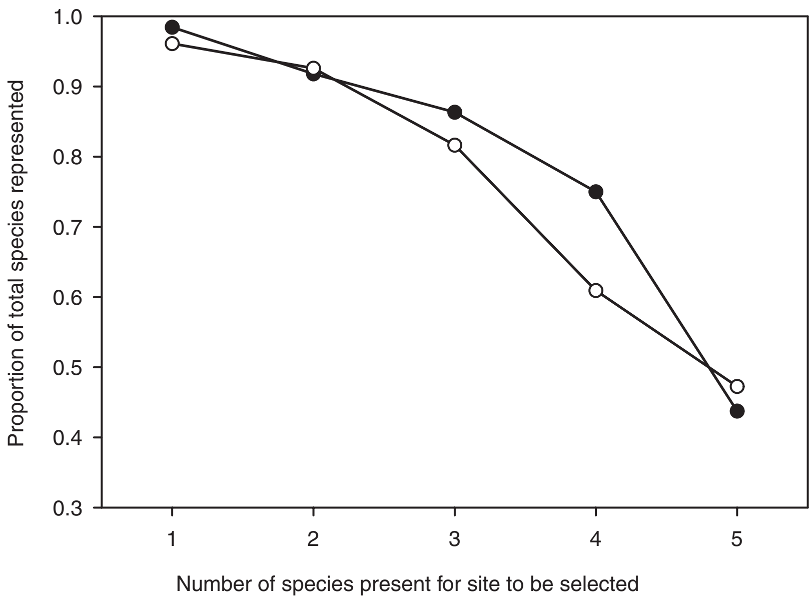

Figure 2. Change in the proportion of the total number of species present across all sites that would be represented if site selection were based on the presence of different numbers of species of the indicator taxa. Filled symbols = Coenagriidae, open symbols = Limnephilidae. (Note: although 13 species of Limnephilidae were recorded across all sites, no site had more than five species present.)

correlation which was not highly significant ($P > 0.001$, Figure 1), although a number of the other taxa assessed also showed strong correlations with the richness of other groups. There was no relationship between the mean cross-taxon correlation and taxon species richness ($r_{[14]} = 0.274$, $P = 0.305$) suggesting that indicator status is independent of taxon richness. Indeed the two taxa with the highest mean cross taxon correlations had relatively low richness (Table 1).

Unsurprisingly, when site selection was based on the presence of an increasing number of indicator taxa species, the proportion of the total species pool represented in the selected sites declined. This is illustrated for the two taxa which were the best candidates for indicator taxa (Coenagriidae and Limnephilidae) in Figure 2. Limnephilidae showed a slightly more rapid rate of decline in proportion of species represented, but for both taxa selection of sites based solely on presence (i.e. at least one species of indicator present) still represented over 95% of the total number of species recorded across all sites.

DISCUSSION

The results of this study suggest that Coenagriidae and Limnephilidae are the most effective indicators of overall pond invertebrate community richness, based on the extent to which the richness of these groups reflects the richness of all other taxa. Both groups also fulfill other suggested criteria for indicator taxa (Pearson, 1994), namely (a) well known taxonomy: there are established taxonomic keys to larval Odonata and Trichoptera in Britain (Hammond, 1983; Wallace *et al*., 1990), (b) readily surveyed: the small number of species in both groups would make survey work easier and they are effectively sampled by standard methods (e.g. Biggs *et al*., 1994a) and (c) present over a wide range of habitat types: ecological information contained in the keys detailed above suggests that species of both taxa are found in a wide range of different habitats. The characteristics of these two groups that make them effective indicators are unclear. It has been suggested that predatory taxa, such as Coenagriidae, should be good indicators due to their dependence on the presence of other taxa as food (Davis *et al*., 1987). However, Limnephilidae are herbivores and detritivores in the main (Wallace *et al*., 1990), and other predatory taxa, such as Gyrinidae or Libellulidae scored poorly (Figure 1). Clearly indicator status is not easily predicted from trophic level, and the response of taxa to habitat diversity or other site characteristics may provide a more general explanation of variation in indicator status.

Based on the present results, if one taxon should be chosen as an indicator of species richness then Coenagriidae would have a marginally better performance than Limnephilidae. A recent study of lakes in Sweden using a different methodology (Sahlen and Ekestubbe, 2001) has also suggested that Odonata are good indicator taxa. The study of Sahlen and Ekestubbe (2001) was carried out at a lower taxonomic resolution (order rather than family) and in this study some Odonata groups such as Libellulidae were poor indicators (Figure 1), suggesting that the taxonomic resolution of studies may influence the assessment of indicator taxa. It may also be expected that the status of particular taxa as indicators may vary with habitat type, and hence taxa that are good pond indicators should not necessarily be good indicators for lakes or other freshwater habitats.

An important limitation of this study is that it only considered invertebrate species richness. The extent to which invertebrate taxa represent the richness of other equally important groups for conservation, such as plants or amphibians, was not assessed. The study of Sahlen and Ekestubbe (2001) found that Odonata were good indicators of plant species richness and presence of the pool frog (*Rana lessonae* Camerano), but previous studies of the relationship between invertebrate and plant richness in pond sites have given conflicting results (e.g. Palmer, 1981; Gee *et al*., 1997).

In addition, this study was based on ponds from a limited geographical area of southern Britain. Prendergast and Eversham (1997) have demonstrated that the covariance of taxon richness may be highly spatially variable. What appear to be good indicators in one geographical area may not be representative of species richness patterns elsewhere. Southern Britain has a relatively high species richness of Coenagriidae (Merritt *et al*., 1996). Further north and west, the number of species present is reduced as species reach their British range limits. Such variation is reflected in the criteria used by the Nature Conservancy Council

(1989) and its successor bodies in the selection of SSSIs in Britain. A dragonfly assemblage is judged to be outstanding if it contains 17 species in southern England, but only seven species in the north of Scotland (Nature Conservancy Council, 1989). Therefore, as a first step towards further evaluation of the proposed indicator taxa, similar assessments should be made for sets of ponds in different geographical regions in order to establish whether indicator status is robust to geographical variation in the size of the species pool. The extent to which environmental variation influences the utility of indicator taxa also warrants further study. Classifications of pond invertebrate communities (e.g. Foster *et al*., 1989) indicate that community composition is influenced by environmental conditions (such as pH). This variation may need to be accounted for when assessing potential indicator taxa.

Indicator taxa as assessed here only represent the overall species richness of sites; the identity of the species present is not considered. Species richness is only one criterion used in the assessment of conservation value (Usher, 1986), and high species richness may result from human impacts such as nutrient enrichment. Often, species-poor sites where indicator taxa may be absent support specialized communities containing rare species such as those characteristic of temporary ponds (Collinson *et al*., 1995; Nicolet, 2001). These are equally valuable for conservation, but may not be well represented by basing selection of sites on indicator taxa alone. In this case, if rare species are defined as those found in three or fewer sites surveyed (the lower quartile of the distribution of numbers of sites occupied: Gaston, 1994), then there is a strong positive relationship between the number of rare species and the number of indicator taxa present (Pearson product moment correlation, Coenagriidae $r_{[128]} = 0.609$, Limnephilidae $r_{[128]} = 0.714$, both $P < 0.001$). This would suggest that assessing pond sites based on indicator taxa also captures information regarding the number of rare species present. However, the generality of this relationship is unclear.

In practice, when assessing sites for conservation it is likely that a range of metrics would be applied (e.g. Boon *et al*., 1997) and decisions based on the overall rating of a particular site by the different methods. Indicator taxa would appear to have merit for the rapid assessment of species richness patterns, and may also be an effective method for monitoring the status of sites following designation. An additional criterion that should be considered when selecting pond sites for conservation is the surrounding landscape. Pond communities at individual sites do not exist in isolation. Many of the taxa present are capable of dispersal between sites, and populations may be influenced by immigration from surrounding habitats. Other authors have emphasized the importance of the regional setting in which sites exist in terms of the connectivity between individual sites (Biggs *et al*., 1994b; Boothby, 1997). When deciding which sites should be selected, indicator richness could be weighted by the site location relative to other selected sites (Briers, 2002), promoting connectivity between sites as well as conserving species richness over regional areas.

ACKNOWLEDGEMENTS

We would like to thank Mike Jeffries, Margaret Palmer and an anonymous referee for perceptive comments on a previous draft of the manuscript.

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