Watsonia **22**: 29–32 (1998)

Relationship between species richness and rarity in Welsh aquatic floras

D. M. WILKINSON

Biological and Earth Sciences, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF

ABSTRACT

Comparison of the biodiversity of sites, such as potential nature reserves, often has to use incomplete data. In such cases rules of thumb, such as a positive correlation between species richness and the presence of rarities, could allow more rational decisions to be made. Such a relationship is tested in two Welsh aquatic data sets. This analysis supports the general positive relationship between species richness and rarity; however in a lake data set no correlation was found between the species richness or number of rarities when the emergent and submersed plant communities were compared; i.e. a site which was good for emergent plants was often not a good site for submersed plants and vice versa. It is suggested that the species richness/rarity rule only applies to tightly constrained, homogenous data sets.

KEYWORDS: nature reserves, biodiversity, botanical surveys, *Pilularia globulifera*.

INTRODUCTION

The preservation of biodiversity is a major aim of applied ecology (Wilson 1992). One of the approaches to this is to construct networks of nature reserves, though serious questions have been raised about this as a long term strategy in the light of continuing environmental change, both natural and anthropogenic (Hunter *et al.* 1988; Huntley 1994). Biodiversity is composed of a variety of measures such as species richness (number of species at a site), species abundance (population size of species of a site) and habitat diversity (Hambler & Speight 1995). In comparing sites, for example in selecting nature reserves, often the main data available are species lists for the better studied taxa (e.g. vascular plants, birds or butterflies). This raises a number of important questions. For example, does species richness of a well studied taxon such as vascular plants positively correlate with species richness of less well studied groups such as beetles (Wilkinson & Slater 1995)? Does species richness in a group correlate with the occurrence of rare species of that group at a site? Selecting sites on the basis of a high species richness could be a mistake if important rare species are found in species poor sites which would not receive protection were such a criterion used (Hambler & Speight 1995).

Such questions can only be successfully addressed in an empirical manner, by investigating the relationships between the occurrence of different taxa, species richness and rarity at a variety of sites. As a contribution to such a research agenda this paper examines the relationship between species richness and rarity in two aquatic flora data sets from Wales, U.K.

THE DATA SETS

Two published data sets on Welsh aquatic floras were used.

1. A set of 36 shallow and often ephemeral upland ponds from mid Wales, ranging in altitude from 320–500 m (Slater *et al.* 1991). These ponds are of particular conservation interest as around half of them contain the aquatic fern *Pilularia globulifera*. This fern is endemic to Europe and threatened throughout most of its range due to loss of habitat through drainage. These mid Wales ponds are one of its strongholds and of international importance (Woods 1993). One site, Park Farm, which

TABLE 1. SPECIES FROM SEDDON (1972) LISTED AS IN NEED OF SPECIAL PROTECTION IN THE WELSH WATER AUTHORITY AREA BY PALMER & NEWBOLD (1983)

Submersed and floating species	Emergent species
Apium inundatum	*Baldellia ranunculoides*
Ceratophyllum demersum	*Butomus umbellatus*
Elatine hexandra	*Carex acuta*
Isoetes echinospora	*C. acutiformis*
I. lacustris	*C. elata*
Lemna trisulca	*C. lasiocarpa*
Lobelia dortmanna	*C. riparia*
Luronium natans	*C. vesicaria*
Myriophyllum spicatum	*Cladium mariscus*
Potamogeton alpinus	*Eleocharis acicularis*
P. crispus	*Hippuris vulgaris*
P. gramineus	*Oenanthe fistulosa*
P. lucens	*Ranunculus lingua*
P. obtusifolius	*Schoenoplectus lacustris*
P. perfoliatus	*S. tabernaemontani*
P. pusillus	*Typha angustifolia*
Ranunculus circinatus	*Veronica anagallis-aquatica*
R. trichophyllus	
Sparganium angustifolium	
S. natans	
Subularia aquatica	
Eleogiton fluitans	
Callitriche hermaphroditica	
C. obtusangula	

Nomenclature follows Stace (1991).

appears in the data set of Slater *et al.* (1991) has been omitted from this analysis as it is a lower, more species rich site in improved farmland and so is atypical of the rest of the data set.

2. A data set of plants from Welsh lakes including both upland and lowland sites (Seddon 1972). This data set is comprised of two subsets: i. submersed and floating aquatic plants from 70 Welsh lakes; and ii. emergent plants from 72 Welsh lakes.

Rare species are those having low abundance and/or small ranges, and this raises the question of how low or how small? This is often affected by factors such as the area under study or the purpose for which the list is being constructed. A single objective definition of rarity which can be applied in all studies of all taxa is unrealistic. This is illustrated by the wide range of definitions of rarity which have been used in the past (reviewed by Gaston 1994).

In this study a rare species is defined as any species listed as "in need of special protection in the Welsh Water Authority area" by Palmer & Newbold (1993). This is an inclusive list containing some quite widespread and locally common species which were however considered to be possibly declining and in need of protection. In the upland pond data set there were two species "in need of special protection", *Pilularia globulifera* and *Apium inundatum*. The lake data set contained a longer list of such species which are listed in Table 1. In the following analysis species richness refers to the total number of species at a site and rarity refers to the number of species listed as "in need of special protection" found at a given site.

RESULTS AND DISCUSSION

The correlations between species richness and rarity for each of the data sets are shown in Table 2. In each case there is a positive correlation significant at $p<0{\cdot}001$, although the correlation coefficients range from 0·500 to 0·722. A number of previous studies on a variety of taxa have found rare species to be positively correlated with species richness (Gaston 1994). For example, Wheeler

TABLE 2. RELATIONSHIP BETWEEN SPECIES RICHNESS AND RARITY IN WELSH AQUATIC FLORAS

Data set	Reference	No. sites	Total no. spp.	Total no. rare spp.	r_s
Upland pools, Mid Wales	Slater *et al.* (1991)	36	66	2	0·722
Welsh lakes (all plants)	Seddon (1972)	54	91	41	0·500
Welsh lakes submersed plants	Seddon (1972)	70	41	24	0·536
Welsh lakes emergent plants	Seddon (1972)	72	50	17	0·631

Note: all correlations significant at $p<0{\cdot}001$.

(1988) found a highly significant ($p<0{\cdot}001$) positive relationship between number of rare species and total species richness for British fen vegetation. In the present study the strength of the correlation varies between data sets. The highest correlation ($r_s = 0{\cdot}722$) is for the upland pond data set where there are only two rare species, *Pilularia globulifera* and *Apium inundatum*, which are significantly associated ($\chi^2 = 13{\cdot}38$, $p<0{\cdot}01$, $n = 36$) in the data set though it included some sites with *Pilularia* but no *Apium* and some with *Apium* but no *Pilularia*. In this case selecting species rich sites would be an effective way of selecting sites with rarities.

The Welsh lake data set is of particular interest. Although there is a significant correlation between species richness and rarity for total species (i.e. all lakes where Seddon (1972) lists data on both submerged and emergent plants), if the submersed and emergent data subsets are compared (Tables 2 & 3 of Seddon 1972) then no significant correlations are found (correlation between submersed and emergent species richness $r_s = 0{\cdot}144$, not significant at $p = 0{\cdot}05$, $n = 54$; correlation between number of rare submersed and number of rare emergent species $r_s = 0.029$, not significant at $p = 0{\cdot}05$, $n = 54$). Therefore good sites for emergent plants tend not to be good sites for submersed plants. This is true whether a "good site" is selected on the basis of species richness or by the presence of rare species. This suggests that correlations between species richness and rarity may be community specific, with a whole lake being too large a unit for analysis as it contains a number of very different communities (e.g. emergent and submersed). This requires investigation by further studies as it is important for comparing sites of nature conservation importance. It is of interest that for the upland pond data set Wilkinson & Slater (1995) found a positive correlation between plant species richness and a measure of general invertebrate species richness but no correlation between water beetle species richness and plant or general invertebrate species richness. This suggests that different taxa as well as different communities can show different patterns of species richness, so that a good site for water beetles may not be a good site for aquatic plants.

These results suggest that caution is required in the make up of data sets when extrapolated from species richness data to rarity richness. For example the relationship between plant species richness and rarity in British fens identified by Wheeler (1988) means that selecting the most species rich sites would also select the sites with the most rarities. However if the exercise were repeated for all British mires then selecting by species richness would miss many rarities as most of the sites selected would be fens as these tend to be more species rich than ombrotrophic mires (Wheeler 1993), so rare ombrotrophic species would be missed. This underlines the suggestion in the data presented above that the species richness/rarity rule is only likely to work for tightly constrained, homogenous data sets. Such heuristic rules, tested on the relatively well known British flora, could be of great use in areas where the flora is less well known, such as tropical forests, which are thought to contain some 40% of the world's flora, sometimes with over 300 species/ha^{-1} (Archibold 1995).

ACKNOWLEDGMENTS

I thank Fred Slater and Ann Hemsley for collaboration in the *Pilularia globulifera* study and Alan Clapham and the referees for comments on drafts of this paper.

REFERENCES

Archibold, O. W. (1995). *Ecology of world vegetation*. Chapman & Hall, London.

Gaston, K. J. (1994). *Rarity*. Chapman & Hall, London.

Hambler, C. & Speight, M. R. (1995). Biodiversity conservation in Britain: science replacing tradition. *British wildlife* **6**: 137–147.

Hunter, M. L., Jacobson, G. L. & Webb, T. (1988). Paleoecology and the coarse-filter approach to maintaining biological diversity. *Conservation biology* **2**: 375–385.

Huntley, B. (1994). Plant species response to climatic change: implications for the conservation of European birds. *Ibis* **137**: 5127–5138.

Palmer, M. & Newbold, C. (1983). *Wetland and riparian plants in Great Britain*. Nature Conservancy Council, Huntingdon.

Seddon, B. (1972). Aquatic macrophytes as limnological indicators. *Freshwater biology* **2**: 107–130.

Slater, F. M., Hemsley, A. & Wilkinson, D. M. (1991). A new sub-association of the Pilularietum globuliferae Tuxen 1955 in the upland pools in the mid-Wye catchment of central Wales. *Vegetatio* **96**: 127–136.

Stace, C. (1991). *New flora of the British Isles*. Cambridge University Press, Cambridge.

Wheeler, B. D. (1988). Species richness, species rarity and conservation evaluation of rich-fen vegetation in lowland England and Wales. *Journal of applied ecology* **25**, 331–353.

Wheeler, B. D. (1993). Botanical diversity of British mires. *Biodiversity and conservation* **2**: 490–512.

Wilkinson, D. M. & Slater, F. M. (1995). Relationship between plant and invertebrate richness in upland ponds in mid Wales. *The naturalist* **120**: 103–108.

Wilson, E. O. (1992). *The diversity of life*. Harvard University Press, Cambridge, Massachusetts.

Woods, R. G. (1993). *Flora of Radnorshire*. National Museum of Wales, Cardiff.

(*Accepted March 1996*)