R. Marchant

Museum of Victoria
Abbotsford, Victoria, 3051 Australia

References

BARTON, D. R. 1996. The use of Percent Model Affinity to assess the effects of agriculture on benthic invertebrate communities in headwater streams of southern Ontario, Canada. Freshwater Biol. **36:** 397–410.

BOWMAN, M. F., AND R. C. BAILEY. 1997. Does taxonomic resolution affect the multivariate description of the structure of freshwater benthic macroinvertebrate communities? Can. J. Fish. Aquat. Sci. **54:** 1802–1807.

BUNN, S. E., D. H. EDWARD, AND N. R. LONERAGAN. 1986. Spatial and temporal variation in the macroinvertebrate fauna of streams of the northern jarrah forest, Western Australia: Community structure. Freshwater Biol. **16:** 67–91.

CAO, Y., D. D. WILLIAMS, AND N. E. WILLIAMS. 1998. How important are rare species in aquatic community ecology and bioassessment? Limnol. Oceanogr. **43:** 1403–1409.

CLARKE, K. R., AND R. M. WARWICK. 1994. Change in marine communities: An approach to statistical analysis and interpretation. Natural Environment Research Council.

FURSE, M. T., D. MOSS, J. F. WRIGHT, AND P. D. ARMITAGE. 1984. The influence of seasonal and taxonomic factors on the ordination and classification of running-water sites in Great Britain and on the prediction of their macroinvertebrate communities. Freshwater Biol. **14:** 257–280.

GAUCH, H. G. 1982. Multivariate analysis in community ecology. Cambridge Univ. Press.

MARCHANT, R. 1990. Robustness of classification and ordination techniques applied to macroinvertebrate communities from the La Trobe River, Victoria. Aust. J. Mar. Freshwater Res. **41:** 493–504.

———, L. A. BARMUTA, AND B. C. CHESSMAN. 1994. Preliminary study of the ordination and classification of macroinvertebrate communities from running waters in Victoria, Australia. Aust. J. Mar. Freshwater Res. **45:** 945–962.

———, ———, AND ———. 1995. Influence of sample quantification and taxonomic resolution on the ordination of macroinvertebrate communities from running waters in Victoria, Australia. Mar. Freshwater Res. **46:** 501–506.

———, A. HIRST, R. H. NORRIS, R. B. UTCHER, L. METZELING, AND D. TILLER. 1997. Classification and prediction of macroinvertebrate assemblages from running waters in Victoria, Australia. J. North Am. Benthol. Soc. **16:** 664–681.

WARWICK, R. M. 1993. Environmental impact studies on marine communities: Pragmatical considerations. Aust. J. Ecol. **18:** 63–80.

WRIGHT, J. F., P. D. ARMITAGE, M. T. F. URSE, AND D. MOSS. 1988. A new approach to the biological surveillance of river quality using macroinvertebrates. Int. Verein. Limnol. Theor. Angew. Verh. **23:** 1548–1552.

Received: 27 January 1999
Accepted: 3 May 1999
Amended: 10 June 1999

Limnol. Oceanogr., 44(7), 1999, 1841–1842

Rare species are important in bioassessment (Reply to the comment by Marchant)

Marchant (1999) has raised some points with respect to our conclusions (Cao et al. 1998) about the importance of rare species in community analysis and bioassessment that are worthy of further discussion. Whereas we indicated that rare species could be important for distinguishing among sites along an impairment gradient, Marchant argues that the weight of evidence suggests otherwise—that ample redundancy in species composition and abundance allows the elimination of rare species from many multivariate analyses without affecting conclusions significantly. Our study warned that environmental practitioners should be alert to situations in which rare species could make a significant difference in bioassessment interpretation. Marchant also questions some of our conclusions. Our detailed responses follow.

First, Marchant disagrees with Cao et al.'s criticism regarding the circular relationship between underweighting rare species in similarity measures and the effect of rare species on multivariate techniques. It is true that log or other forms of data transformations can increase the weight of less abundant and rare species. Cao et al. (1997) demonstrated how the transformation reduced the bias of overweighting abundant species inherent in most similarity measures (including Euclidean Distance, Bray–Curtis Index, and Percentage Similarity), but they also showed that the bias could not be eliminated by a log transformation, which complicated some others (e.g., Canberra Metric). Marchant suggests that the agreement between the solutions from binary (presence/absence) and quantitative data supports his argument. However, other explanations exist. For example, whether and how the solutions from the two types of data sources are different will depend on how strong the pattern is. If a pattern is obvious, both types of data are sufficient to detect it, and even the presence of just a few dominant/common species may be enough. We agree with Marchant that the agreement indicates that most of the information is contained in species composition rather than in relative/absolute species abundance. However, less abundant and rare species typically dominate the taxonomic makeup of natural systems, and the effectiveness of binary data supports the importance of rare species.

Marchant further suggests that emphasizing rare species is equivalent to denying the redundancy in community data. This argument is not logical. Whereas data sets do contain redundant information, Marchant does not demonstrate that it is the rare species information that is necessarily the redundant part for bioassessment. Defining community types or a major environmental gradient is different from detecting impacts (*see below*). Indeed, it can be strongly argued that, in contrast, it is those abundant species that respond to the same environmental factor in a similar way, or that covary along the same gradient, that represent most of the redundant information. Hence, variations in the most common species (particularly ubiquitous species) are most likely to generate noise in the data set; this is why data transformation is needed (also, *see* Cao et al. 1997).

We agree with Marchant that it would have been helpful if we had been able to compare the results of rapid bioassessment protocols (RBP) from different-sized samples. However, any such comparison could not be generalized except across many studies, such as in a meta-analysis. The sample size required is related to the true difference to be detected, but human impacts range over a wide spectrum, from slight to severe. It is highly risky, therefore, to extrapolate the sample size effective in a case study to world systems in general.

Marchant questions our assertions about the effectiveness of multivariate models based on 200–300 individuals. Multivariate analysis can be used for direct assessment, i.e., determining an impact by examining temporal–spatial patterns. The question that Cao et al. (1998) raised is directly related to this application. Vegetation ecologists have a long history of defining community types based on just one or two dominant species (although their studies on communities go far beyond this). If multivariate analyses are used for a similar purpose, rare species will likely be ignored. However, the question in bioassessment is different: Is an ecosystem affected and to what extent? Can we define impact only as negative change in a small number of abundant species? Is not species loss itself an important part of an impact—or a signal of environmental degradation? If removing a large proportion of species does not influence our pattern analysis, are we to conclude that the pattern remains even if all the rare species become extinct? Although such pattern analysis may be useful for some purposes, we must be cautious when interpreting its results in terms of biological monitoring.

Multivariate approaches also are used to develop multivariate models for predicting the occurrence of species, which is only indirectly related to our study. The case that Marchant mentions appears to fall within this category. A model based on small quantitative samples, which almost certainly will exclude the majority of less abundant and rare species, would be able only to predict the occurrence of abundant species and would be subject to concerns similar to those outlined above.

When Marchant places his trust in small samples (200–300 individuals), he must implicitly assume that an impact always influences abundant/common species first and to the greatest degree. However, there is no support for this assumption, either from toxicological studies or field surveys. Indeed, some general observations suggest the opposite. Rarity usually means either widespread distribution in low numbers or restricted distributions. In both cases, rare species are more sensitive to disturbance than abundant species. Furthermore, in a variety of organism groups, local species abundance is typically correlated positively with their distribution (Brown 1984; Gaston and Lawton 1990; Hanski et al. 1993; Hanski and Gyllenberg 1997). This means that abundant species tend to be distributed widely or are tolerant of a variety of environmental conditions, whereas low species abundance is frequently coupled with restricted distribution—which makes rare species doubly vulnerable to disturbances (Lawton 1993; Gaston 1998). This phenomenon is a central tenet of conservation ecology. Rare species should be appropriately weighted for sensitive and robust bioassessment or, more broadly, in ecological monitoring.

Yong Cao

U.S. EPA NHEERL-WED
200 SW 35th Street
Corvallis, Oregon 97333

D. Dudley Williams

Division of Life Sciences
University of Toronto at Scarborough
1265 Military Trail
Scarborough, Ontario, Canada M1C 1A4

References

BROWN, J. H. 1984. On the relationship between abundance and distribution of species. Am. Nat. **124:** 253–279.

CAO, Y., D. D. WILLIAMS, AND N. E. WILLIAMS. 1998. How important are rare species in community ecology and bioassessment. Limnol. Oceanogr. **43:** 1403–1409.

———, W. P. WILLIAMS, AND A. W. BARK. 1997. Similarity measure bias in river benthic Aufwuchs community analysis. Water Environ. Res. **69:** 95–106.

GASTON, K. J. 1994. Rarity. Chapman and Hall.

———. 1998. Ecology: Rarity as double jeopardy. Nature **394:** 229–230.

———, AND J. H. LAWTON. 1990. Effects of scale and habitat on the relationship between regional distribution and local abundance. Oikos **58:** 329–335.

HANSKI, I., AND M. GYLLENBERG. 1997. Uniting two general patterns in the distribution of species. Science **275:** 397–400.

———, J. KOUKI, AND A. HALKKA. 1993. Three explanations of the positive relationship between distribution and abundance of species, p. 108–116. *In* R. E. Ricklefs and D. Schluter [eds.], Species diversity in ecological communities: Historical and geographical perspectives. Univ. of Chicago Press.

LAWTON, J. H. 1993. Range, population abundance and conservation. Trends Ecol. Evol. **8:** 409–413.

MARCHANT, R. 1999. How important are rare species in aquatic ecology and bioassessment? A comment on the conclusions of Cao et al. Limnol. Oceanogr. **44:** 1840–1841.

Received: 12 May 1999
Accepted: 10 June 1999