Ann. Zool. Fennici 39: 3–6 ISSN 0003-455X
Helsinki 6 March 2002

Correcting species richness hotspots for latitudinal gradients: a new method

Janne S. Kotiaho & Matti Hovi*

University of Jyväskylä, Department of Biological and Environmental Science, P.O. Box 35, FIN-40351 Jyväskylä, Finland
**Current address: Finnish Forest and Park Service, Torangintaival 2, FIN-93600 Kuusamo, Finland*

Received 9 October 2000, accepted 13 December 2000

Kotiaho, J. S. & Hovi, M. 2002: Correcting species richness hotspots for latitudinal gradients: a new method. — *Ann. Zool. Fennici* 39: 3–6.

Species richness hotspots are of critical importance in conserving biodiversity, but by using simple species richness in an area, there is an inevitable bias in favour of lower latitudes. We propose a simple method for estimating regionally representative species richness hotspots where the effect of latitudinal gradients is accounted for. By using this method, the same number of species are conserved but instead of being concentrated on lower latitudes the selected areas fall into much larger geographical regions resulting in a broader range of habitat types conserved. This method suits any scale and is also applicable to other kinds of environmental gradients. These points are illustrated with data on birds and dragonflies of Finland.

Introduction

In the modern world, conservation of biodiversity has become an increasingly important issue and there is a growing political will to find the best way to measure conservation values. In particular those responsible for the management of habitats need scientific methods for ranking different areas for conservation. Even though the biological nature of the habitats under the consideration may differ tremendously, there is a need to simultaneously evaluate and rank these areas. From the biological perspective there are several ways of evaluating the conservation value of the different areas (Spellerberg 1992), but often these methods are complicated and not easily applicable in practise.

There are three major approaches to the study of biodiversity: firstly the latitudinal, or other geographical gradient approach (Fisher 1960, Currie & Paquin 1987, Turner *et al*. 1988, McCoy 1990, Rohde 1992, Stevens 1992, Rex *et al*. 1993), which stems from the long tradition of community ecology, and secondly the species richness hotspots approach (Myers 1988, Prendergast *et al*. 1993, Williams *et al*. 1996). Latitudinal gradients have a strong influence on species richness and a well recognised pattern is that species richness increases from the poles towards the equator. This general pattern has a clear influence on the hotspots approach: most of global-scale species richness hotspots are situated in the tropics (Miller 1992, Jablonski 1993). The third, and currently perhaps most widely used, approach is complementarity approach (Pressey *et al.* 1993, Williams *et al.* 1996, Howard *et al.* 1998). This method combines the within-site species richness with between sites differences and therefore requires knowledge of the identities of all species.

Species richness hotspots are frequently used in evaluating and ranking areas for conservation (Spellerberg 1992). However, because of the latitudinal species richness gradients this approach may often lead to the conclusion that the most valuable areas are located in lower latitudes and the true value of areas in higher latitudes may remain undetected. We feel that this may be a flawed method for assessing species richness, and that conservationists should look for areas that are relatively most species rich i.e. areas with high species richness which arises not because of the latitude alone. Therefore, to be able to evaluate the species richness hotspots correctly the effect of latitudinal gradients needs to be considered.

Relative species richness method

We propose a simple method for estimating the species richness hotspots where the effect of latitudinal gradients is accounted for. With our method, regionally representative species richness hotspots can be found which is of critical importance in designing conservation plans. We will first explore this approach through a case study on the species richness of birds in Finland. We used birds because there are accurate (10 ¥ 10 km) atlas data (Hyytiä *et al.* 1983) on the distribution of birds breeding in Finland (235 species). We divided the whole area of Finland (ca. 338 000 km^2, length south–north ca. 1100 km) into squares of 50 ¥ 50 km. Altogether there were 158 squares within 22 latitudinal bands of 50 km (3 to 11 squares per band). First we calculated number of species observed to breed in each of the squares (S_s). Then we regressed ($Y = a + bX$) these numbers onto their latitudinal bands and took the residuals ($S_s - Y$). By dividing the residuals ($S_s - Y$) with the expected value (Y) of species richness for each band from the regression we get a relative measure (I) of species richness:

$$I = (S_s - Y)/Y \qquad (1)$$

where I is the new relative species richness index, S_s = number of species in the square and Y is formula for linear regression $Y = a + bX$.

This index is dependent on the expected number of species for each latitude but independent of the latitude *per se*. Furthermore, this measure is independent of the number of the squares per row (area effect on species richness) since it is calculated by using the whole data and thus this method may also be used in irregularly shaped areas. In addition, this method may be applied in any other kinds of gradients for example altitude, moisture, temperature or light. In fact, the gradient may be any environmental variable, which correlates with species richness, but is not of conservation interest itself. These points will be illustrated with our data.

Two empirical examples

The latitude alone explained 70.2% of the variation in species richness of the squares. Thus, there is a clear pattern of latitudinal species richness gradient in birds of Finland (Fig. 1A). However, the variance explained by latitude drops to 0.2% when we look at the relative species richness index (Fig. 1B). This example on Finnish birds illustrates our point well: if species richness hotspots alone were used in evaluating the conservation value of each of these 50 ¥ 50 km squares, most valuable areas would be situated in the southernmost parts of Finland. However, if the method of relative species richness hotspots described above was used, there would also be valuable conservation areas in northern Finland. Furthermore, if we look at the number of species occurring in the top 5 squares based on our relative species richness index or on simple species richness alone we end up with almost identical number of species (193 vs. 195 respectively), while at the

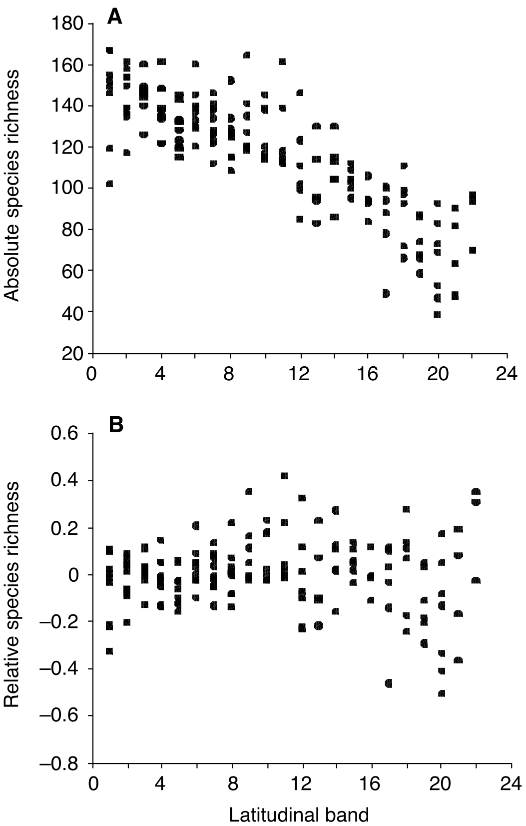

Fig. 1. — **A**: The number of bird species in 50 ¥ 50 km squares in relation to latitude (Y = 155.70 – 3.80X; r^2 = 0.702, $F_{1,156}$ = 367.52; P < 0.001). The latitude refers to arbitrary bands of 50 km. — **B**: Relative species richness index for birds in relation to latitude (Y = 0.01 – 0.09E–02X; r^2 = 0.002, $F_{1,156}$ = 0.25; P = 0.615). The latitude refers to arbitrary bands of 50 km.

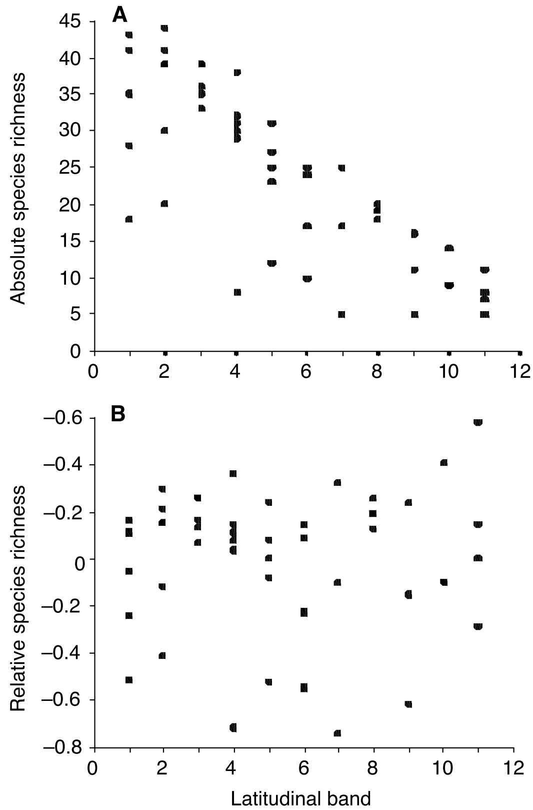

Fig. 2. — **A**: The number of damselfly and dragonfly species (Odonata) in 100 ¥ 100 km squares in relation to latitude (Y = 39.89 – 2.99X; r^2 = 0.638; $F_{1,46}$ = 80.96; P <0.001) The latitude refers to arbitrary bands of 100 km. — **B**: Relative species richness index for Odonata in relation to latitude (Y = 0.01 + 0.04E–01X; r^2 = 0.001, $F_{1,46}$ = 0.06; P = 0.801). The latitude refers to arbitrary bands of 100 km.

same time the geographical area covered by the scatter of the top 5 squares based on our relative species richness index is more than twice of that covered by scatter of squares based on simple species richness (130 000 km^2 vs. 60 000 km^2). The geographical area covered is estimated as (50 km times the number of squares between the furthest western and furthest eastern square inclusive) times (50 km times the number of squares between the furthest southern and the furthest northern square inclusive).

In another example, we plotted the number of dragonfly (Odonata) species found in 100 ¥ 100 km squares in Finland (51 species) (Valtonen 1980). A highly significant negative relationship between latitude and species richness (63.8% of variation explained; Fig. 2A) disappeared when the relative species richness index was calculated as above (0.1% of the variation explained, Fig. 2B). Again, number of species from the 5 top squares with relative species richness index and simple species richness is almost the same (44 and 47 respectively), but the geographical area covered based on our relative species richness index is six times larger than that based on simple species richness (180 000 km^2 vs. 30 000 km^2 respectively). The geographical area covered is estimated as (100 km times the number of squares between the furthest western and furthest eastern square inclusive) times (100 km times the number of squares between the furthest southern and the furthest northern square inclusive). Evidently, applying relative species index leads to the conservation of broader range of habitat types.

Conclusions

The advantage of the approach described above is in its simplicity: if there are data available on number of species in a given area one can always calculate the relative species richness index. We acknowledge that when species identities are known complemetarity approach (Pressey *et al.* 1993, Williams *et al.* 1996, Howard *et al.* 1998) should be employed, but propose that the relative species richness approach may be useful tool when only number of species is known. Another advantage of our method is that it may be used in a wide range of scales from local to large global scale conservation plans, although it is intuitively obvious that the scale has to be appropriate for the organism and prioritisation problem in question. Particularly useful this method is on national scale; very often the areas that are most species rich are also the most wanted areas for other purposes such as agriculture. Therefore, by applying our method it is possible to conserve the same number of species without the need to enter to the costly competition for areas that are constrained by other needs than conservation.

Acknowledgments

We thank Tomi Kumpulainen for evoking our interest in the measurement of diversity hotspots. Comments and advice from Harri Högmander and Jukka Suhonen improved our way of thinking considerably and we are thankful for helpful comments from Andrew Balmford, Veijo Kaitala, Lotta Kvarnemo, Mikko Mönkkönen, Leigh Simmons and Joseph Tomkins. This work was supported by the Academy of Finland.

References

Currie, D. J. & Paquin, V. 1987: Large-scale biogeographical patterns of species richness of trees. — *Nature* 329: 326–327.

Fisher, A. G. 1960: Latitudinal variations in organic diversity. — *Evolution* 14: 64–81.

Howard, P. C., Viskanic, P., Davenport, T. R. B., Kigenyi, F. W., Baltzer, M., Dickinson, C. J., Lwanga, J. S., Matthews, R. A. & Balmford, A. 1998: Complementarity and the use of indicator groups for reserve selection in Uganda. — *Nature* 394: 472–475.

Hyytiä, K., Kellomäki, E. & Koistinen, J. 1983: *Suomen lintuatlas*. — SLY:n Lintutieto OY, Helsinki.

Jablonski, D. 1993: The tropics as a source of evolutionary novelty through geological time. — *Nature* 364: 142–144.

McCoy, E. D. 1990: The distribution of insects along elevational gradients. — *Oikos* 58: 313–322.

Miller, G. T. 1992: *Living in the environment*. — Wadsworth, California.

Myers, N. 1988: Threatened biotas: "hot spots" in topical forests. — *The Environmentalist* 8: 187–208.

Prendergast, J. R., Quinn, R. M., Lawton, J. H., Eversham, B. C. & Gibbons, D. W. 1993: Rare species, the coincidence of diversity hotspots and conservation strategies. — *Nature* 365: 335–337.

Pressey, R. L., Humphries, C. J., Margules, C. R., Vane-Wright, R. I. & Williams, P. H. 1993: Beyond opportunism: key prinsiples for systematic reserve selection. — *TREE* 8: 121–128.

Rex, M. A., Stuart, C. T., Hessler, R. R., Allen, J. A., Sanders, H. L. & Wilson, D. F. 1993: Global-scale latitudinal patterns of species diversity in the deep-sea benthos. — *Nature* 365: 636–639.

Rohde, K. 1992: Latitudinal gradients in species diversity: the search for the primary cause. — *Oikos* 64: 514–527.

Spellerberg, I. F. 1992: *Evaluation and assessment for conservation*. — Chapman & Hall, London.

Stevens, G. C. 1992: The elevational gradient in altitudinal range: an extension of rapoport's latitudinal rule to altitude. — *Am. Nat.* 140: 893–911.

Turner, J. R. G., Lennon, J. J. & Lawreson, J. A. 1988: British bird species distribution and the energy theory. — *Nature* 335: 539–541.

Valtonen, P. 1980: Die Verbteirung der Finnishen Libellen (Odonata). — *Notulae Entomol.* 60: 199–215.

Williams, P., Gibbons, D., Margules, C., Rebelo, A., Humphries, C. & Pressey, R. A. 1996: Comparison of richness hotspots, rarity hotspots, and complementaty areas for conserving diversity of british birds. — *Conserv. Biol.* 10: 155–174.