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Nothing has yet lasted forever: current and threatened levels of biological and cultural diversity

Lisa L. Manne*

Centre for Biodiversity Research, University of British Columbia, 6270 University Boulevard, Vancouver, British Columbia V6T 1Z4, Canada

ABSTRACT

We still do not understand why some areas are more biologically diverse than others. There are broad generalities over large scales, but each group of species has its own idiosyncrasies: historical, evolutionary and environmental factors that combine to effect the distribution of diversity that we observe. Some of these factors may be similar for some groups of species, and this similarity will be reflected in like distributions for those groups. However, 'biodiversity' applies both within species and between species, but comparisons of biodiversity patterns between and within species have rarely been done. Distribution information for our own species, humans, is available, and we can examine the within-species diversity pattern of human cultures across the landscape. I use number of languages as a proxy for cultural diversity and I compare the within-species biodiversity pattern for humans to that for Passeriform birds, across species. At a coarse resolution I find spatial concordance between the two over large areas in Central and South America, which cannot be explained by a single shared mechanism of resource dependence for the two groups: different combinations of environmental variables result in high or low diversity for birds and languages. The concordance between birds and languages weakens at finer scales, which highlights the different scales at which these two groups operate. Finally, it has been suggested that processes that remove cultural diversity might also threaten species. However, I find that where there are more threatened cultures there are few threatened species. This might be explained by the genocides perpetrated in Central and South America before many languages were adequately documented. While the analogy between biodiversity and cultural diversity cannot be general for all scales and areas, given the immense differences in history and various other factors, the correspondence observed across and within species in these two groups is remarkable.

Keywords: biodiversity, cultural diversity, language diversity, threatened languages, threatened species.

INTRODUCTION

Taxonomic classification of species and classification of languages share many concepts and terms in common: phylum, family, clade and group. Languages are grouped into

* Address all correspondence to Lisa Manne, Biogeography and Conservation Laboratory, Natural History Museum, Cromwell Road, London SW7 5BD, UK. e-mail: l.manne@nhm.ac.uk

families of languages; families are grouped into stocks. Both systems (languages, species) are hierarchical. Both systems justify this hierarchical approach via similar assumptions entailing underlying processes of descent with modification. It is easy to see why cultures and species have been likened in the literature (Harmon and Maffi, 2002).

Several factors are believed to increase the diversity of human cultures in an area: isolation, access to resources (Nettle, 1998), low latitude (Mace and Pagel, 1995; Nettle, 1998; Collard and Foley, 2002), low climatic variation (Nettle, 1998), proximity to coastline (Nichols, 1992) and efficient food production (Bellwood, 1996). Isolation, low latitude and resource-rich areas have also proved to be good indicators of biological diversity (Ceballos and Brown, 1995; Renjifo *et al.*, 1997), so that we might expect linguistic and biological diversity to coincide. Further, the rate of loss of cultures is rapid (Blench, 1998; Grinevald, 1998; Krauss, 1998), and if the same processes operate to threaten peoples and species, the loss of cultures in a region may presage the later loss of species.

Nettle (1999) models the stock diversity of a region as an initial colonization and radiation, followed by a long decline, as groups expand and compete with other groups. 'Extinction of language' is often achieved through 'shift', wherein one language moves towards another language, so that over time the differences between the two languages are reduced. Languages can shift very quickly (Nichols, 1992; Schilling-Estes and Wolfram, 1999), making the study of linguistics a moving target. Thus, the youngest languages and language groups make better subjects for study in this analysis. The Americas make an excellent study region, as the loss of languages by shift is thought to be minimal there.

In this paper, I examine whether there is indeed a coincidence between biological and cultural diversity, analyse the validity of a resource-based shared mechanism and then test whether a coincidence between threatened species and cultures exists.

METHODS AND RESULTS

As an index of cultural diversity, I digitized the geographic ranges of human languages found in Central and South America (Ricardo, 1996; Grimes, 2000) at a resolution of 1°. I included both 'native' languages (spoken by indigenous peoples) and 'colonial' languages (Spanish-, English- and Portuguese-speaking peoples, among others), since all people in the Americas are derived from colonists, from hundreds to thousands of years ago (Hughes and Hughes, 1994). As an index of biological diversity, I use Passeriform bird distributions, digitized at 1° (Manne *et al.*, 1999).

As proposed by some authors (Mishler, 2001; Smith, 2001; Collard and Foley, 2002) and supported recently (Moore *et al.*, 2002), one would expect spatial concordance between numbers of languages and numbers of species. In Fig. 1, I show numbers of species (a), numbers of cultures (b) and the comparison (Williams, 2000) of the two (c) per 1° grid cell in Central and South America. At this scale, these appear to be highly and significantly correlated: a Spearman rank test yields a correlation (r) of 0.37, significant at $P < 0.0001$. This result persists when using a modified t-test (Dutilleul, 1993) to account for loss of degrees of freedom due to spatial autocorrelation ($r = 0.24$, $P < 0.0001$). In Fig. 1a,b, warmer colours indicate higher numbers of species and languages. In Fig. 1c, there are large areas where levels of cultures and biodiversity are both high (pink, large parts of the Andean region, northern Bolivia and the Guianan shield) or both low (black, northern Chile, southern Chile and Argentina, and the eastern Argentine coast). Green and blue areas show discordance; the former areas (near the Amazon River, much of eastern

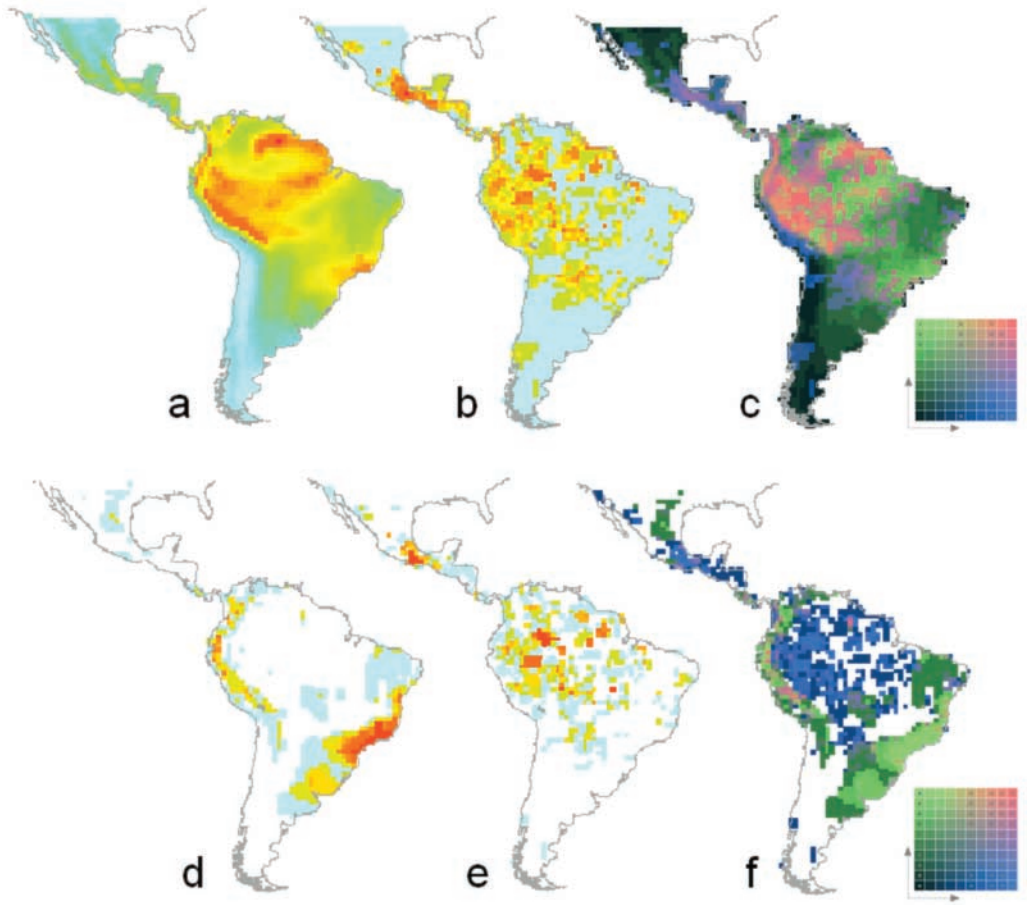

Fig. 1. Maps of (a) passeriform species richness, (b) linguistic richness, (d) number of passeriform birds with fewer than 10,000 mature individuals (satisfying the IUCN C and D1 threat criteria), (e) number of languages having fewer than 10,000 speakers (as a measure of threatened languages). In these maps, cool/warm colours indicate low/high numbers of birds or languages. Part (c) shows bird species richness overlaid with linguistic richness; part (f) shows threatened birds overlaid with threatened languages. In these maps, pink/black colours show regions with high/low levels of both birds and languages. Green areas are regions with a preponderance of birds (or threatened birds) over languages (or threatened languages); blue areas have proportionately more languages (threatened languages) than birds (threatened birds). For all maps, the axes are equal-frequency transformed. White areas show no data.

Brazil) contain more biodiversity relative to cultural diversity. Perhaps these green areas are true exceptions to the broad-scale concordance (pink and black areas) between species and languages in Fig. 1c, or it may be that indigenous cultures are incompletely sampled or under-reported in Brazil. The blue areas (the Bolivia–Argentina border, the western slope of the southern Andes and the Mexican isthmus) contain a preponderance of linguistic diversity. This last exception may be due to over-splitting of the languages of the Mexican isthmus (Kaufman, 1994a).

At this scale of analysis, there is a remarkable correspondence between cultural diversity and biodiversity. However, Fig. 2 shows a plot of number of bird species versus number of languages, from these maps. Both the largest and the smallest numbers of birds occur in grid cells containing five or fewer languages, while the highest numbers of languages occur in grid cells containing intermediate numbers of birds. Thus, there is no simple monotonic relationship between numbers of species and languages.

Since the relationship in Fig. 2 is not simply monotonic, I examined whether birds and cultural groups use the environment in the same way. If they do, then a common resource-based mechanism favouring both high biodiversity in passeriform birds and high cultural diversity might be supported. I used the following environmental variables as predictors of the number of passeriform species or languages in a 1° grid cell: minimum and maximum elevation, annual minimum and maximum precipitation, annual minimum and maximum temperature, annual minimum and maximum actual evapotranspiration, and productivity (Uchijima and Seino, 1985). A non-parametric regression tree analysis (Breiman *et al.*, 1984) yields very different combinations of environmental variables resulting in high or low diversity of species and languages (Fig. 3). For bird species in Central and South America, the highest diversities are in areas that have greater than 3.75 mm average yearly precipitation and latitutudes above 18°S; for languages, the highest diversities are in areas that have average yearly evapotranspiration over 108 mm, average annual precipitation over 9 mm and elevations of less than 200 m. At the lower end of the spectrum, the lowest diversities of birds are in areas with a maximum yearly temperature less than 23°C and less than 3.75 mm average yearly precipitation; for languages, the lowest diversities tend to be in areas with evapotranspiration less than 108 mm, or in areas with evapotranspiration greater than 108 mm, elevations above 200 m and precipitation below 9 mm per year.

From these results, it would appear that species and cultures are not utilizing their environments in similar ways, and perhaps very different processes led to diversification and/or maintenance of species and cultural groups. There is also evidence for differing

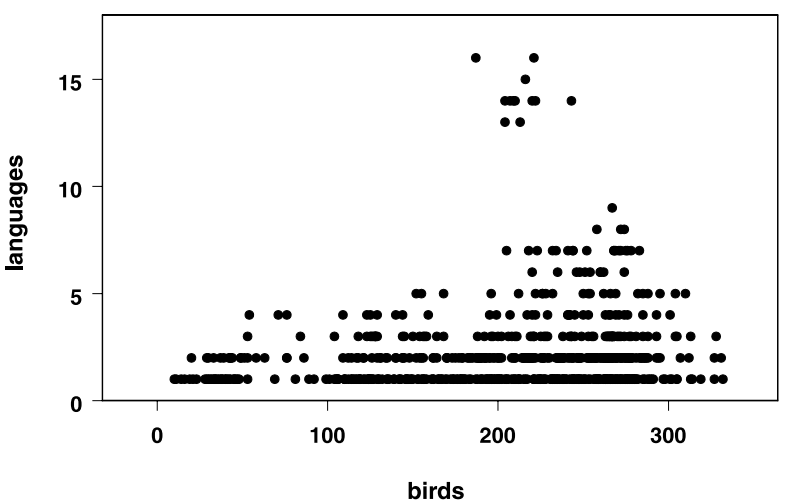

Fig. 2. Plot of numbers of bird species in a 1° grid cell versus numbers of languages. Both the largest and the smallest numbers of birds occur in grid cells containing five or fewer languages, while the highest numbers of languages occur in grid cells containing intermediate numbers of birds.

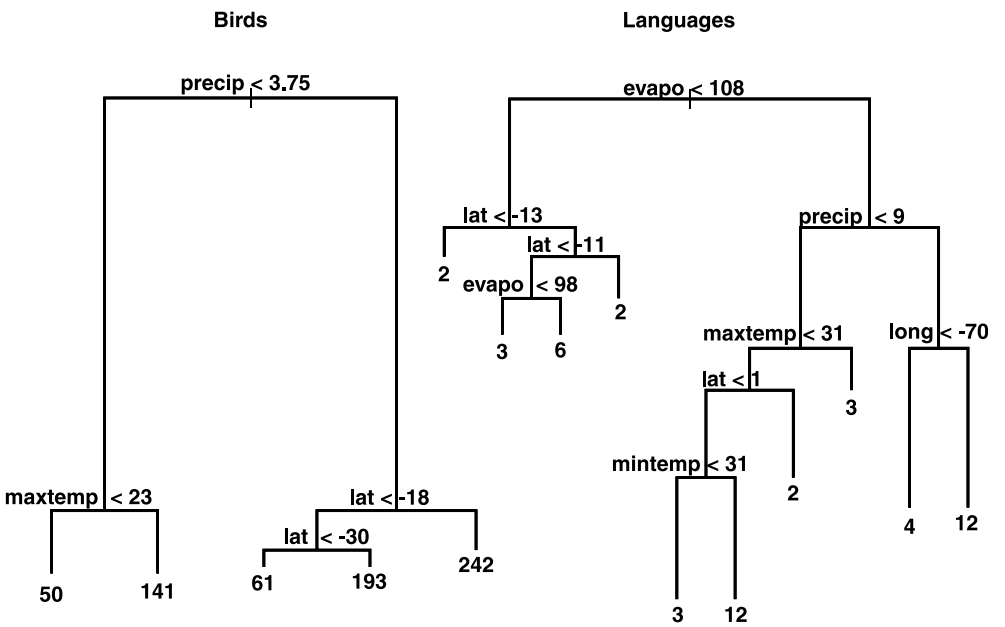

Fig. 3. Regression trees showing the predicted number of birds (left) or languages (right) based on combinations of environmental conditions in a grid cell. Different environmental conditions lead to high or low diversity in birds and languages. Precip = precipitation; evapo = evapotranspiration; lat = latitude; long = longitude; maxtemp = the maximum annual temperature; elev = elevation.

spatial scales of some processes in the different frequency distributions of range sizes between cultural groups and species: birds tend to have much larger geographic ranges than languages (Fig. 4). I will return to this point in the Discussion.

Different processes may have led to the diversification of species and cultural groups, but given that they do tend to co-occur (no matter what the explanatory mechanism), similar processes might still lead to the loss of both species and human groups. A cultural group could be lost because (a) the entire population dies out (e.g. they all contracted the same, fatal disease) or (b) the culture of the group shifts towards that of another. The latter could be the result of a conquering event (one ethnic group conquers the other and has a zero-tolerance policy towards the conquered group's customs) or may reflect new trade or land-use patterns in the region. For instance, a poorer ethnic group may wish to trade with a richer ethnic group nearby, in which case it is advantageous for the former to learn the latter's language and customs. Over time, there may be more advantage to knowing the richer group's language, and the poorer group's language may become obsolete. Changing land-use patterns may also speed the shift of languages or even the demise of languages (Pimm, 2000). Diamond (1997), drawing on the work of Bellwood (1996) and Renfrew (1996), implicates the spread of agriculture in the loss of languages. Krauss (in Hale *et al.*, 1992) cites the more general 'habitat destruction' as one force among many that contributes to culture loss.

One hypothesis, following the reasoning of Krauss, is that habitat destruction or modification will affect both cultures and species in similar ways, and that we should therefore

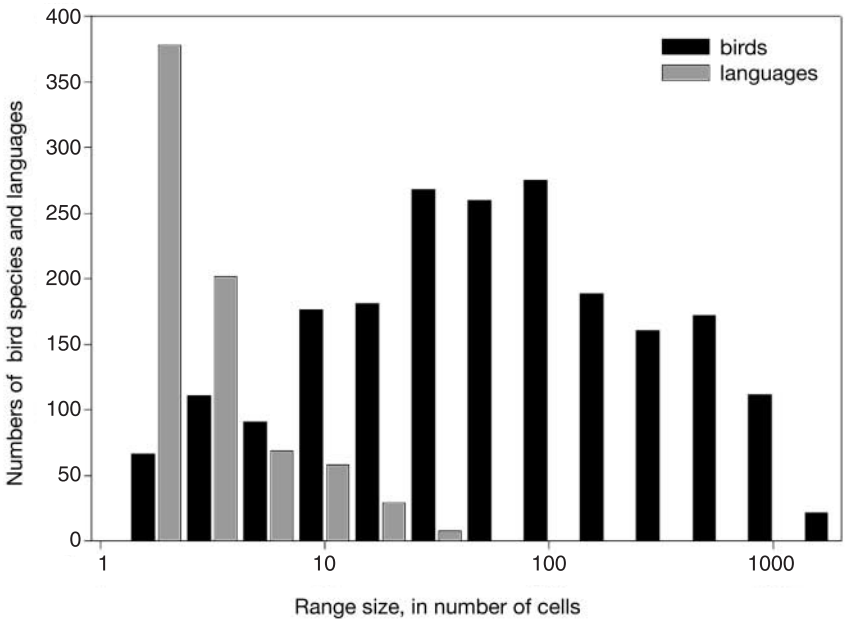

Fig. 4. Frequency distribution of geographic range sizes (measured in numbers of 1° grid cells) of passeriform bird species (■) and languages (■). The typical range of a language is an order of magnitude smaller than that for a bird species.

expect to see a spatial correspondence between threatened cultures and threatened species. To compare these two groups requires a consistent definition of what constitutes 'threat' or 'risk of extinction' for a language and a species. The International Union for the Conservation of Nature (IUCN) has a long history of defining threat for species based on size or decline of the geographic range, population and extent of habitat, or on more direct pressures like hunting or capture for the caged animal trade (Mace and Lande, 1991).

For languages, there is less precedent for defining threat, but there is a movement towards using a threshold number of speakers as a characterization of extinction risk. Krauss (in Hale *et al.*, 1992) divides languages into three groups: moribund (not being learned by children as a mother tongue language), safe and neither. He goes on to say that a language having more than 100,000 speakers might reasonably be called 'safe'. Pimm (2000) echoes this thought. Krauss feels that this threshold may be conservative, citing Navajo and Breton as having more than 100,000 and 1 million speakers, respectively, yet facing uncertain futures. Grinevald (1998) agrees that even the relatively high number of speakers of some South American languages is not a guarantee against extinction. Nevertheless, defining threat for a language based on a threshold number of speakers allows a preliminary comparison with species. A very conservative characterization of threat for a language might be having fewer than 10,000 speakers, which can be matched with the IUCN categories C and D1: species that are estimated to have fewer than 10,000 mature individuals.

I compared the distributions of passeriform birds satisfying the IUCN categories C or D1 in Central and South America (Stattersfield and Capper, 2000) to the distributions of threatened languages, as characterized above. There are 542 threatened languages in this region (under my conservative definition of language endangerment; Fig. 1e) and 88 bird species satisfying the C or D1 criteria of the IUCN (Fig. 1d). Threatened birds and languages are compared in Fig. 1f (Spearman $r = -0.66$, $P < 0.0001$). Red or pink colours indicate locations where both cultural and biological endangerment are high. Green areas show a relative preponderance of endangered birds; blue areas show relatively higher proportions of endangered languages. Black areas show low levels of biological and linguistic endangerment; areas with neither linguistic nor biological endangerment are white. In contrast to the diversity relationship (Fig. 1c), threatened languages tend to be in different places than threatened species: Fig. 1f is mostly green, blue or white. The few exceptions, where there are relatively high numbers of both endangered languages and species (pink), are in central Costa Rica and at various locations in moderate to high altitudes in the Andes. Consequently, endangered languages cannot be used as a predictor of endangered species.

DISCUSSION

All languages versus only 'native' languages

An important question is whether to include all languages or only 'native' languages in the analyses. Including all languages removes the need to impose a possibly artificial distinction between 'languages that count' and 'languages that don't count'. On the other hand, why should one expect that environmental factors would help to explain the distribution of groups speaking colonial languages? At the level of political units, 'linguistically homogeneous' countries (dominated by few, widespread languages) tend to be wealthier than 'linguistically fragmented' countries (Nettle, 2000). Wealthier countries are less likely to be tied to the landscape making a living through subsistence. The exclusion of languages/ethnic groups from linguistically homogeneous countries in the diversity analysis above might result in a stronger relationship between biodiversity and linguistic diversity in Fig. 1c.

To test for these confounding effects, I re-analysed the diversity regression and mapping using only indigenous ethnic groups: those which derive from peoples that walked into Central and South America, rather than the more recent peoples that arrived by sea. Languages excluded here are: Spanish, English, Plautdietsch, Portuguese, Romani, Chinese (Hakka and Yue), French, Caribbean Javanese, Caribbean Hindustani, German and Dutch. The statistical inferences are not changed by excluding the colonial peoples.

Possible incomplete sampling of human cultural groups

Figure 2 shows that there is a bimodal distribution of language numbers. The areas with the highest numbers of languages, corresponding to a group of outliers at the top of the graph, are from three regions in South America: at the border of Colombia and Brazil, in southern Brazil and at the border between Bolivia and Peru. It may be that South America is sampled unevenly, with some locations being extremely well-known and others less so. The Summer Institute of Language (Grimes, 2000) has not established a presence in Paraguay

or Venezuela, and no longer maintains a presence in Colombia or Bolivia (Grinevald, 1998). Discovering more cultures in these regions might make the language frequency distribution (Fig. 2) more nearly unimodal, but it is unlikely to change the results of Fig. 1c substantially, as those countries already show relatively high numbers of both languages and species.

Languages that have already been lost

Hundreds of South American indigenous languages were lost in the colonial period (Kaufman, 1994b). Perhaps these languages were from areas where the threatened species are concentrated. In an attempt to test for this effect, I digitized the extinct languages listed in *Ethnologue* (Grimes, 2000) for which I could compile location data (44 of 86). Of those 44 languages, only 16 are in areas with bird species that have fewer than 10,000 individuals. However, genocides perpetrated by the government or by parties interested in possession of land and resources (Horowitz, 1976; Kuper, 1977) have been documented in the areas considered here both in Brazil (Davis, 1971) and in Argentina (Darwin, 1860) from the colonial period. Forcible eviction of indigenous peoples for timber or mineral extraction happens to this day, in some cases involving complete destruction of indigenous possessions and violence towards the evicted people.

Inclusion of hitherto lost languages in these analyses might substantially alter these results, perhaps resulting in more comparable maps of threatened language- and species-richness. However, at this point in time, many languages have already been lost without complete documentation.

Strength of correlation and resolution of study

Previous studies at a relatively coarse scale, either on a country by country basis (Harmon and Maffi, 2002) or at a coarse resolution (Moore *et al.*, 2002), have found a strong correlation between species diversity and cultural diversity. However, at very fine scales, languages tend not to overlap in space (see maps in Grimes, 2000; Bellwood, 2001), but rather to occupy separate territories. In contrast, bird ranges overlap, with many species even within one hectare. At such a fine resolution, there will usually be only a single language per grid cell but possibly many bird species, leading to little or no detectable coincidence between biodiversity and language diversity. Therefore, the resolution of an analysis will affect the observed strength of the correlation.

I examined the effect that the resolution of the analysis has on the strength of the coincidence observed in Fig. 1c between numbers of species and languages. Is the relationship as strong when the resolution is changed? In Fig. 5, I plot the birds–languages correlation against the spatial resolution of the analysis, as resolution of the grid cells decreases from $1^\circ \times 1^\circ$ to $6^\circ \times 6^\circ$. Figure 5 shows that, as the resolution of the analysis becomes more coarse, the observed strength of the correlation increases. At scales of 2° or more, the correlation between biodiversity and cultural diversity appears relatively strong. However, Fig. 5 shows that the coarse scale is potentially misleading, as it only reveals part of the story, and that the relationship tends to break down at finer scales. More work is needed to tease apart how the strength of patterns of coincidence in biodiversity and cultural diversity changes with resolution.

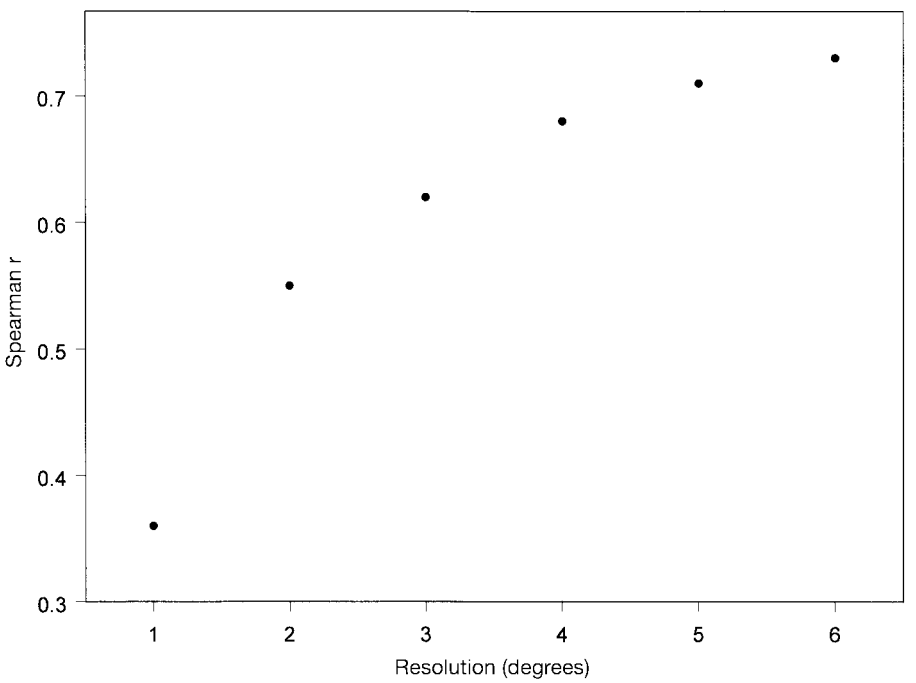

Fig. 5. Spearman rank correlation coefficients between bird species and languages at different spatial resolutions. The correlation increases as resolution becomes more coarse; at resolutions of 2° or more, the correspondence appears very strong.

Distribution of threatened languages is constrained

Threatened language richness is closely related to overall language richness. The only way to have many languages per 1° cell is for the languages to have small ranges (Fig. 4) and, most likely, to have few speakers. Necessarily, then, hotspots of threatened languages are constrained to be concentrated in the same places as hotspots of all language richness. But as noted above, many bird species often co-exist on the same patch of land. Consequently, there is greater scope for the threatened bird species to be distributed uniformly across the landscape, or to be concentrated in locations different from those of highest species richness (subject to geometric constraints imposed by the shapes of continents and of biogeographic regions; Jetz and Rahbek, 2001). For these reasons alone, endangered bird species and endangered cultural groups are not likely to be coincident.

CONCLUSION

In conclusion, species diversity and cultural diversity coincide at very coarse scales for these species in Central and South America. A key difference between bird species and human cultures is that bird species are much more able to co-exist (and so can have much larger range sizes; Fig. 4). For cultures, smaller ranges (and small numbers of individuals in a cultural group) may render them much more vulnerable to threats that completely disrupt

their way of making a living (e.g. conversion to agriculture or eviction for resource extraction). The two groups of organisms use the environment in different ways so that environmental variables are not predictive of concordant diversity. A consequence is that the resolution of the analysis dramatically changes the diversity maps. It is only at very coarse resolutions that diversities coincide. At this point in time, endangered biodiversity and endangered cultural diversity do not coincide at any resolution. Consequently, we should not generally expect spatial congruence in distributions of richness or of endangerment between biological and cultural diversity.

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