

Quantity versus quality: Endemism and protected areas in the temperate forest of South America

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Abstract Identification of biodiversity hotspots is essential to conservation strategies aimed at minimizing the possibility of losing half of the world's species in the next 50 years. The aims of the present study were: (i) to locate and designate zones of endemism in the temperate forest of South America; and (ii) to compare the distribution of these areas with the distribution of existing protected areas in this habitat type. Endemism areas were determined by using parsimonious analysis of endemism, which identified zones of endemism on the basis of sets of endemic species that were restricted to two or more study areas. We used distribution information for five unrelated taxa (ferns, trees, reptiles, birds and mammals) to provide more reliable results and patterns than would work with only a single taxon or related taxa. The northern part of this region has high endemism for all of the taxa considered in this study. We demonstrate that although the temperate forest of South America has more than 30% of its area under some type of protection, correlation between protected areas and the areas of endemism is remarkably low. In fact, less than 10% of protected areas are situated in areas that have the greatest value for conservation (i.e. high endemism). Under the current strategy, biodiversity within South America's temperate forest is in danger despite the large amount of protected area for this forest type.

Key words: conservation, endemism, parsimonious analysis of endemism, protected area, temperate forest of South America.

INTRODUCTION

Global biodiversity is heavily threatened, and understanding patterns of biodiversity distribution is essential to conservation biology (Ehrlich 1992; Grehan 1993; Lamoreux *et al.* 2006; Soule & Sanjayan 1998). Confronted with this extinction crisis, efficient conservation strategies often focus either on areas with high species richness or on areas that contain large numbers of endemic species, identifying these as conservation hotspots (Lamoreux *et al.* 1997; Myers *et al.* 2000; Olson *et al.* 2001). Historical approaches used to select areas for conservation, however, have largely selected areas in an *ad hoc* fashion. This approach often identified areas with scenery, tourist potential, recreational opportunities, or areas with low commercial value or that provide habitat for hunting (Pressey 1994). One major disadvantage of the *ad hoc* selection of conservation areas is that areas are chosen outside the context of a regional reserve system; leaving important areas of

high endemism without substantial protection (Pressey 1994).

One promising approach for conserving biodiversity is identifying areas with high endemism that also are experiencing extraordinary habitat loss (Myers 1990; Myers *et al.* 2000). An area of high endemism usually is characterized by the occurrence of two or more exclusive species (Platnick 1991; Bates *et al.* 1998). Although correlation among areas with high species richness and high endemism may be low, areas with high levels of endemism tend to contain significantly more species than expected by chance (Lamoreux *et al.* 1997). Aside from the identification of areas with unique biota for conservation, other reasons exist for examining areas of endemism (Lamoreux *et al.* 1997; Stattersfield *et al.* 1998; Myers *et al.* 2000). First, examining areas of endemism elucidates the biogeographical history of a region, and second, it allows hypotheses about the evolution of species present in these areas (Cracraft 1985; Cardoso da Silva & Conway Oren 1996).

Temperate forests of South America are of special interest for conservation, because they exist as a biogeographical island isolated by geographical barriers,

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from other biota with similar fauna and flora. These forests are isolated by deserts on their eastern and northern borders and by the Pacific Ocean towards their western limit. The similarities in the composition of the fauna and flora date from the Tertiary era, when temperate forests extended in a continuum throughout South America, New Zealand, Australia, and Antarctica (Briggs 1987). This community is an example of a biome that has a great number of endemic species: 34% of angiosperm genera, 23% of reptilian species, 30% of bird species, 33% of mammal species, 50% of fresh water fish species and 76% of amphibian species are endemic and a large proportion of its flora depends on mutualistic animals (Armesto *et al.* 1996; Aizen & Ezcurra 1998; Aizen *et al.* 2002). This level of mutualism is one of the highest recorded for a temperate ecosystem and is comparable to those from tropical forests (Willson *et al.* 1989; Willson 1991). Unlike the mutualism structure in tropical forests, mutualisms in temperate forests are characterized by a high degree of asymmetry; many species of flora depend on a few mutualistic animals for their survival (Aizen *et al.* 2002). As a result of these fragile interconnections and high endemism level, these forests are considered a region of global conservation concern (Myers *et al.* 2000).

The northern portion (about 41°S) of these forests, which presently has the highest rate of disturbance, also has the highest biodiversity and endemism but the lowest proportion of protected area (Armesto *et al.* 1998). Biodiversity within this area is currently at risk from the highest rates of destruction, fragmentation, and degradation ever experienced. More than 120 000 ha of native forest are destroyed or degraded annually (Lara *et al.* 1996; Echeverría *et al.* 2006).

Earlier studies in this temperate forest, and in other parts of the world, have focused on the analysis of endemism and geographical distribution for single taxa (Gentili 1988; Morrone 1996; Posadas 1996; Lamoreux *et al.* 1997; Posadas *et al.* 1997; Stattersfield *et al.* 1998; Orme *et al.* 2005). Only one study has compared the distribution of species richness, endemism areas for woody flora and vertebrates, and the distribution of regions of human activity with the distribution of reserve areas (Armesto *et al.* 1998). This study, however, occurred solely within the Chilean temperate forest and did not consider relationships within the Argentine temperate forest. This is problematic given the substantial portion of the forest that exists in Argentina and the number of national parks and reserves in this region.

This study's aims were: (i) to analyse the geographical distributions of plant and animal species endemic to temperate forests throughout South America in order to identify areas of endemism; and (ii) to compare them with the distribution of national parks and reserves within this forest type. We also evaluated the suitability

of these areas for conservation. Using more than one group of distantly related organisms may provide more reliable results and patterns than working only with large taxa (García-Barros *et al.* 2002).

METHODS

Study area

Temperate forests of South America extend latitudinally from 35° to 56° south, covering southern Chile and south-eastern Argentina (Armesto *et al.* 1998). This forest is characterized by a great biological diversity and by an annual precipitation gradient from west to east ranging from 4000 to 400 mm in less than 100 km. Similar components of its flora and fauna can be found in forests situated in New Zealand, eastern Australia and Tasmania (Dimitri 1977).

Parsimonious analysis of endemism

Areas of high endemism were determined by using parsimonious analysis of endemism (PAE) (Rosen 1988; Morrone 1994; Morrone & Crisci 1995). PAE identifies areas of endemism by using sets of endemic species that are restricted to two or more study areas (Morrone 1994). Endemism areas can be expressed using a cladistic analysis of a matrix in which the units of area represent the taxa, and the species are used as characters (Rosen 1988; Morrone 1994).

Parsimonious analysis of endemism was carried out for each of the five taxa using the program PAUP 3.1.1 (Swofford 1993). We obtained the most parsimonious trees through an intensive search and selected the consensus tree only when we had more than one parsimonious tree. The consensus tree was then used to identify the species that were restricted to certain clades (subregions). We obtained five consensus trees to represent the synapomorphies, autapomorphies, parallelisms and reversions. An area of high endemism occurred whenever a subregion or a set of subregions had at least two synapomorphies or autapomorphies. Finally, we compared indicated areas of high endemism with the distribution of national parks and reserves in the temperate forests across South America.

Division of the study area

The region was subdivided into nine arbitrary subregions using Peter's (1989) map of projection. A higher resolution of the subregions is not appropriate for the present knowledge of the fine-scale distributions of some taxa. Because performance of a PAE does not require that all subregions have the same size and shape (Posadas 1996; Posadas *et al.* 1997), we divided the region as follows: from 35°S to 54°S we measured

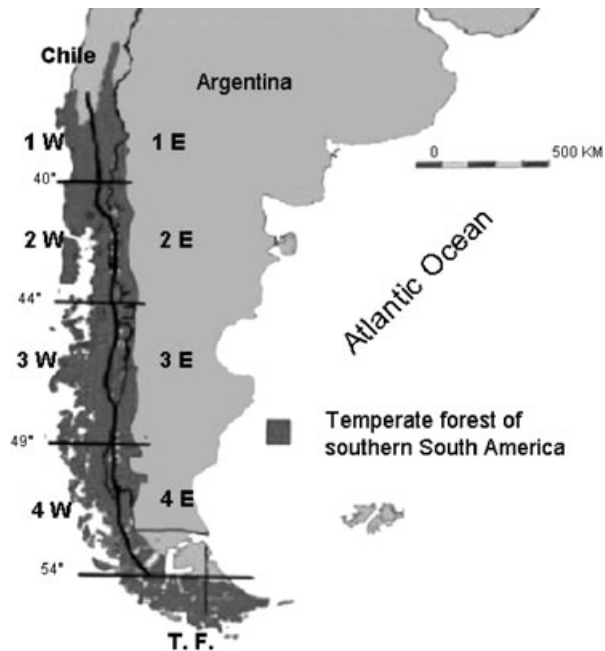


Fig. 1. Map of the temperate forest of South America, showing the nine subregions in which the forest was divided to analyse the distribution of the endemic species (the number and characters represent the nine subregions used in the analysis).

the median distance every 80 km between the Pacific coast of Chile and the eastern limit of the forest in Argentina. We did not include islands when creating subregions. We arbitrarily delimited two large regions of forest; one on the eastern side and the other on the western side of an imaginary line (Fig. 1). Beginning from south of 40°S, we considered three additional imaginary lines every 480 km, effectively separating the region into nine subregions. Distribution of the subregions were: two north of 40°S (1W, 1E), two others between 40°S and 44°S (2W, 2E), two between 44°S and 49°S (3W, 3E), and another two between 49°S and 54°S (4W, 4E). Finally, we included the Tierra del Fuego Island (T.F.) as one subregion.

Selection of data for geographical distribution

We constructed a data matrix that used columns as species and rows as subregions. The presence of a species in a subregion was coded with a 1 and the absence with a 0. We recorded presence or absence information for 122 endemic species in each of the nine subregions. We also included a hypothetical subregion, where all of the species were absent (external group) and added it to each matrix. Species were selected according to the best information available on their distributions. Our data included species information for 15 ferns (Marticorena & Rodríguez 1995; Correa 1998), 37 trees (Erize 1977; Dimitri

1977; Donoso Zegers 1995), 19 reptiles (Donoso Barros 1966; Cei 1986), 27 birds (De La Peña & Rumboll 1998) and 24 mammals (Redford & Eisenberg 1984). Species are listed in the appendix (<http://www.ecolsoc.org.au/What%20we%20do/Publications/Austral%20Ecology/AE.html>) but are referred to by number in the rest of this paper.

RESULTS

For all groups of organisms considered in the present study except reptiles, we identified the occurrence of large endemism areas with successive smaller areas supported by species with a smaller distribution, defining a nested pattern (Table 1, see statistics in Table 2). For avian species, the entire temperate forest is an area of high endemism. The majority of endemic areas identified for this group also were located approximately north from 44°S (Fig. 2D). For tree species, a large area of endemism was identified in subregions 1W, 1E, 2W, 2E and 3W (Fig. 2B). Mammals species showed a trend similar to tree species in their endemism areas (subregions 3E, 1W, 1E, 2W, 2E, 3E and 3W) (Fig. 2E). Ferns and reptilians had major endemism areas in the north of the analysed region (subregions 1W, 1E, 2W and 2E) (Fig. 2A,C). Table 1 shows congruence between endemism areas.

In South America, close to 40% of temperate forests (total area = 39.5 million ha) is under at least one type of protection (Laclau 1997). In south-central Chile, there are 56 national parks and reserves, which protect ~12.8 million ha of temperate forest, and in Argentina eight protected areas, national parks and reserves protect ~1.5 million ha (Laclau 1997; Armesto *et al.* 1998; Martín & Chehébar 2000) (Table 3). There are notable differences in the level of protection between the southern portion (below 44°S) and the northern portion of the temperate forest, with 1.9 million ha protected in the north and 12.6 million ha protected in the south (Table 3).

DISCUSSION

The location of national parks and other reserves in the temperate forest across South America appear to have low overlap with areas important for conservation (i.e. areas of high endemism) as identified by our study. Our results agree with conclusions obtained for areas of endemism within the Chilean portion of this community (Armesto *et al.* 1998). Almost 87% of existing protected areas are situated south of 44°S, whereas we identified nine of the 15 areas of endemism occurring north of 44°S. This region is the only area that contains areas of endemism for all taxa, which highlights this region as an area of high biological value and thus of great importance for conservation.

Table 1. Congruence between endemism areas for all groups

Groups	Area	1W	1E	2W	2E	3W	3E	4W	4E	T. F.	Species that justified the area
Birds	1	×	×	×	×	×	×	×	×	×	1 2 3 10 11 12 14 15 18 19 20 22 23 25 26
	2	×	×	×	×	×	×	×	×		5 8 13 24
	3	×	×	×	×		×				9 17
	4	×	×	×	×						6 27
Trees	1	×	×	×	×	×					31 35 36 37 8 9 10 18 30
	2	×	×	×	×						20 26 27 28 34 5 11 12 13
Mammals	1	×	×	×	×	×	×				15 4
	2	×	×		×						20 19 17
Ferns	1	×	×	×	×						18 14
	2	×	×	×							8 4
	3				×						11 7 3
Reptilians	1	×	×	×	×						16 10 7
	2		×								15 14 13 1
	3			×							12 11 8
	4						×				19 18 6 4 3

T.F., Tierra del Fuego Island.

Table 2. Statistics for each one of the five consensus trees

Group	Length	Consistence index	Retention index
Birds	29	0.93	0.93
Trees	47	0.79	0.88
Mammals	35	0.69	0.72
Ferns	25	0.60	0.65
Reptilians	22	0.86	0.75

Table 3. Protected areas in the temperate forest of Chile and Argentina

Region	Chile		Argentina	
	Area (Ha)	Qty	Area (Ha)	Qty
1	296 732	13	713 913	3
2	606 542	14	286 700	2
3	4288 656	17	115 000	1
4	6040 246	11	600 000	1
T.F.	1541 507	1	63 000	1
Total	12 773 683	56	1 778 613	8

T.F., Tierra del Fuego Island.

Strategies for global conservation solely based on the recommendation that at least 10% of each country or biome should be under some type of protection may not protect biodiversity, because biodiversity is not homogeneously distributed (Gaston 2000; Rodríguez *et al.* 2004). Additionally, the creation of several protected areas without consideration of endemism may not appropriately represent regional biodiversity. This appears to occur within temperate forests of South America, where more than 35% of the total area is under some type of protection. Less than 10% of the

area (~1.9 million ha) that supports the greater number of endemic species is currently protected. This study concurs with Armesto *et al.* (1998), since our analysis of the entire temperate forest (as opposed to solely Chilean areas) indicates that the northern portion of this community in Argentina has larger reserves than the same northern portion in Chile. This arrangement should supposedly result in better protection for these biodiverse areas of the forest, but the protected areas here are not large enough to compensate for the intensive human use and destruction presently occurring.

Protected areas in the temperate forest of South America have been assigned using *ad hoc* selection, where the identification of areas with high values for conservation has been seldom a requirement to create a protected landscape (Burkart *et al.* 1991; Dinerstein *et al.* 1995; Martín & Chehébar 2000). Historically, creation of national parks in this region has been relegated to identifying areas with high scenic or recreational value or with a low economic cost (Régimen legal de los Parque Nacionales Monumentos Nacionales y Reservas Nacionales 1980; Burkart *et al.* 1991; Noss & Cooperrides 1994; Dinerstein *et al.* 1995; Henríquez 1996). A negative consequence of this selection process is seen in Chile, where areas with highest species richness and endemism correlated with areas most exploited by anthropogenic activity. National parks and reserves in Chile are also located in areas with comparatively low species richness and a low rate of endemism (Lara *et al.* 1996; Armesto *et al.* 1998).

Conservation strategies for temperate forests in South America do not currently adequately protect the greatest number of unique species. In addition to anthropogenic disturbances, natural disturbances also present a threat for the biodiversity of the region. The frequency of volcanic eruptions here is one of the highest in the world, and fires (of natural and anthro-

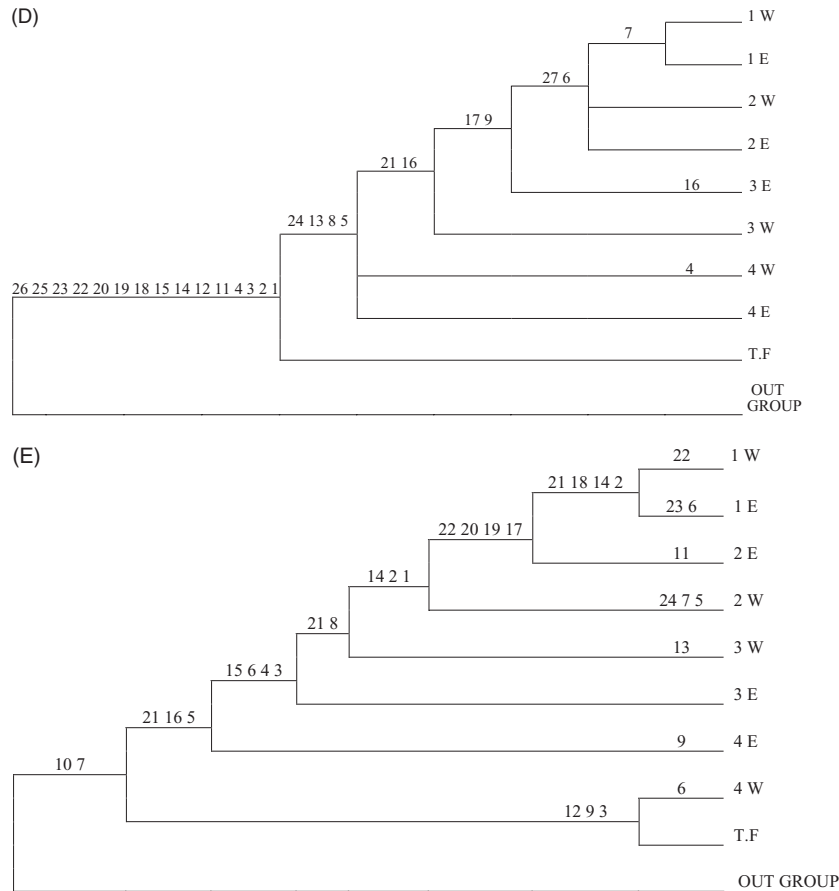


Fig. 2. Continued

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