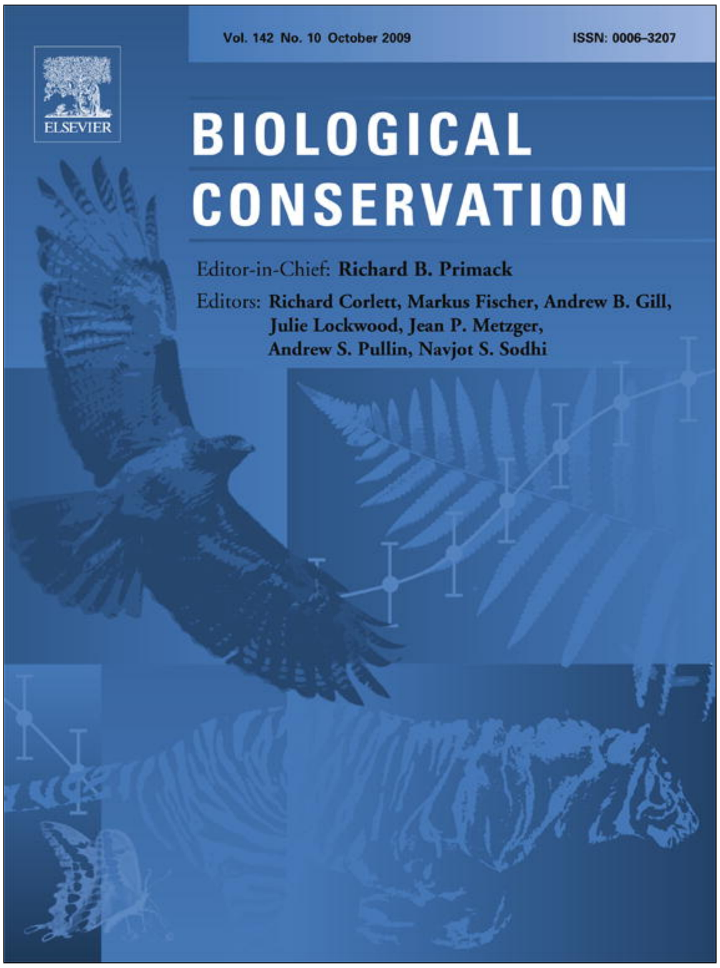
Vol. 142 No. 10 October 2009
ISSN: 0006-3207
ELSEVIER
BIOLOGICAL CONSERVATION
Editor-in-Chief: Richard B. Primack
Editors: Richard Corlett, Markus Fischer, Andrew B. Gill, Julie Lockwood, Jean P. Metzger, Andrew S. Pullin, Navjot S. Sodhi

Biological Conservation 142 (2009) 2329–2334

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Size of protected areas is the main determinant of species diversity in orchids

Iva Schödelbauerová [a,*], David L. Roberts [b,c], Pavel Kindlmann [a,d]

[a] Department of Theoretical Ecology, Institute of Systems Biology and Ecology AS CR and Faculty of Biological Sciences, University of South Bohemia, Branišovská 31, CZ-370 05 České Budějovice, Czech Republic
[b] Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AB, UK
[c] Museum of Comparative Zoology, Harvard University, 26 Oxford Street, Cambridge, MA 02138, USA
[d] Institute for Environmental Studies, Faculty of Science, Charles University, Benátská 2, CZ-128 01, Prague 2, Czech Republic

ARTICLE INFO

Article history:
Received 31 January 2008
Received in revised form 7 May 2009
Accepted 12 May 2009
Available online 11 June 2009

Keywords:
NDVI
Orchidaceae
Protected area
Species–area
Species richness

ABSTRACT

Efficient allocation of conservation resources will be achieved only if the priorities for biodiversity conservation – the "hotspots" – are correctly defined. To achieve this we need to pinpoint the main determinants of species diversity. Area, energy available and latitude are thought to be the most important determinants of species richness. Area is clearly the most important, but the relative importance of the other two is uncertain. To test the relative importance of energy available and latitude, data on the species richness of orchids was collected for various countries in the world, the influence of area factored out and the residuals correlated with energy available at these countries and with latitude. This was performed for both total area and that of the protected areas for the 67 countries from five continents, in order to determine which gives a better prediction. We show that – at the large scale considered – area is always very important, latitude is more important than energy available and the size of the protected areas gives a better fit than the total area of the country in most cases. This implies that conservation efforts should be directed to maximizing the size of the protected areas in each country.

1. Introduction

One of the most pressing issues facing the global conservation community is how to distribute limited resources between regions identified as priorities for biodiversity conservation – the "hotspots" (Possingham and Wilson, 2005; Wilson et al., 2006). However, the efficient allocation of conservation resources will be achieved only if the hotspots are correctly defined. To achieve this we need to pinpoint the main hotspots.

Questions concerning species diversity have attracted ecologists for over a century. Increase in species richness from the poles to the tropics (Pianka, 1966; Rohde, 1992; Willig et al., 2003; Hillebrand, 2004) and with area (Arrhenius, 1921; Gleason, 1922; Williamson, 1988; Rosenzweig, 1995) is still one of the main topics in contemporary ecology. More recently, the amount of energy available (i.e. that which can be converted into biomass) for net primary productivity has been revealed to be an important determinant of species richness (Wright, 1983; Wylie and Currie, 1993a,b; Pelkey et al., 2000; Evans et al., 2005; Storch et al., 2005). Area is clearly the most influential determinant, but the relative importance of the other two factors has been little studied.

In many taxa, especially those confined to natural habitats which have declined in size in recent years, most of the diversity is now concentrated in protected areas. The orchid family, with its enormous species diversity, but extreme susceptibility to disturbance of natural habitats (Kati et al., 2004; Padmawathe et al., 2004; Flores-Palacios and Valencia-Díaz, 2007; Jacquemyn et al., 2007), is one of the best examples. At present, protected areas in the agricultural/industrial landscape can be considered as habitat islands (Begon et al., 1990; Shriver et al., 2004; McDonald et al., 2008), i.e., islands of remnants of natural vegetation surrounded by a landscape that is unsuitable for many species (Forman, 1995). Thus, species richness may be more closely correlated with the size of protected areas rather than with total area.

To test the relative importance of total area, size of protected areas, energy available and latitude, we compiled data on species richness of orchids for various countries worldwide, factored out the influence of area and then correlated the residuals with the mean Normalized Difference Vegetation Index (NDVI, a measure of energy available in these countries – see Section 2) and with latitude. We did this for both the total area of the country and for the size of protected areas available in each country, in order to determine which is the better predictor.

2. Methods

The counts of orchid species recorded in 67 countries on five continents (Africa, Asia, Europe, North and South America) were extracted from the published orchid floras for each country. The

* Corresponding author. Tel.: +420 387 775358; fax: +420 387 775357.
E-mail addresses: ivascho@seznam.cz (I. Schödelbauerová), d.roberts@kew.org (D.L. Roberts), pavel.kindlmann@centrum.cz (P. Kindlmann).

0006-3207/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biocon.2009.05.015

assumption was made that the whole area of each country was surveyed. The list of countries and relevant literature references are included in Appendix A. Tropical and Temperate America were delineated in accordance with the natural boundaries of the tropical/temperate regions, i.e. tropical America is in the range from the tropic of Cancer to the tropic of Capricorn. The country was considered to be tropical or temperate depending on the location of the majority of its area. The country selection was based on the following criteria: orchid flora of the country is available, and the country is sufficiently large so that NDVI and data on the size of the protected areas within the country is available. The total area of the countries and data concerning the size of protected areas of the countries (categories *I*–*V* characterized by the IUCN) in 2004 were obtained for each country from The Environmental Information Portal (http://earthtrends.wri.org/searchable_db). Nature reserves, wilderness areas and national parks belong to the categories *I* and *II*; natural monuments, species management areas and protected landscapes are included in the categories *III*–*V*. Mean latitude of each country is taken as the centroid of the area of the country.

The Normalized Difference Vegetation Index (NDVI) was used as a measure of the energy available to the assemblage. NDVI is strongly and positively correlated with green-leaf biomass, green-leaf area, and absorbed photosynthetically active radiation; it has been viewed as providing reasonable representations of net primary productivity and vegetative growth of terrestrial ecosystems at continental and global scale (Ustin et al., 1991; Kerr and Ostrovsky, 2003), and thus is a suitable measure of the energy available to consumers. NDVI is derived from the visible and near infrared channel reflectances (0.58–0.68 μm and 0.73–1.10 μm, respectively). It is a dimensionless number with typical range from −0.200 to 0.730. This data set was produced as part of the NOAA/NASA Pathfinder AVHRR Land program (http://disc.gsfc.nasa.gov/interdisc/readmes/pal_NDVI.shtml) and monthly data sets are available at a spatial resolution of a 1° latitude/longitude grid. We used mean NDVI values for the main growing season, i.e., mean NDVI for January–April for the southern hemisphere and mean NDVI for May–July for the northern hemisphere.

For the number of species, S, and total or protected area, A_{tot} and A_{prot}, respectively, we calculated the species–area dependences, $S = cA_{tot}^z$ and $S = cA_{prot}^z$ for each continent. We used the residual sum of squares (RSS) as the criterion of goodness-of-fit (the lower the RSS, the better the fit).

For each of the 67 countries we then calculated the values of $Res_{tot,i} = \ln(S_i) - z \cdot \ln(A_{tot,i})$ and $Res_{prot,i} = \ln(S_i) - z \cdot \ln(A_{prot,i})$, where S_i is the number of species in the country i, $A_{tot,i}$ is the total area of the country i, $A_{prot,i}$ is the size of protected areas in the country i and c and z (see the previous paragraph) are the parameters of the species–area dependence calculated for the continent to which the country i belongs. These values, $Res_{tot,i}$ and $Res_{prot,i}$, are therefore the residuals of the species–area dependences, normalized per unit area. By using the residuals instead of number of species in subsequent analyses we factored out the effect of area, which enabled us to study the influence of other variables, such as NDVI and latitude. For this purpose, we correlated these residuals with $\ln(NDVI_i)$ and latitude, L_i (positive for both northern and southern hemisphere), of the country. Thus, we estimated the parameters a, b of the regressions $Res_{tot} = a + b * \ln(NDVI)$ and $Res_{prot} = a + b * \ln(NDVI)$ for each continent separately. We used GLM (General Linear Models) with Res_{tot} and Res_{prot} as dependent factors and ln(NDVI) as a predictor. Similarly, we estimated the parameters c, d of the regressions $Res_{tot} = c + d * L$ and $Res_{prot} = c + d * L$, to determine the influence of latitude. We used GLM with Res_{tot} and Res_{prot} as dependent factors and latitude, L, as a predictor. All the calculations were performed using the package Statistica vs. 5.5, StatSoft, Inc., Tulsa, USA.

3. Results

When RSS was used as a criterion, protected area predicted the number of species better than total area of a country on three out of five continents and for tropical America the prediction was the same; only for Europe was the total area a slightly better predictor (Table 1). Further, protected area explained more of the variability (the dependence was associated with a larger R^2) than the total area, except for Europe, where there was no difference (Table 2). The influence of ln(NDVI) on species richness, after the effect of total or protected area was removed, was ambiguous and usually very weak: a positive correlation was observed for Africa, a negative one for tropical America, while no significant correlation ($p > 0.05$) was found for any other continent (Table 2). However,

Table 1
Parameters z, c and RSS of the species–area dependence when total area (A_{tot}) and protected area (A_{prot}) were used. Better predictions of total area vs. protected area are in bold.

		Africa	Europe	Asia	Whole America	Tropical America	Temperate America
A_{tot}	z	0.16	0.18	0.27	0.22	0.23	0.24
	c	31.8	7.1	17.2	57.3	67.5	3.1
	RSS	443,939	**13,788**	1,553,049	14,580,921	**8,629,648**	4,351
A_{prot}	z	0.34	0.03	0.23	0.27	0.22	0.19
	c	8.5	48.4	53.7	67.3	129.1	13.4
	RSS	**297,679**	16,232	**1,270,763**	**12,582,072**	8,837,892	**3,338**

Table 2
Parameters a, b and the associated R^2 and p of the dependences $Res_{tot} = a + b * \ln(NDVI)$ and $Res_{prot} = a + b * \ln(NDVI)$ of the residuals of species richness, normalized per unit area, on ln(NDVI), when total area or protected area were used. Values of $p < 0.05$ and $R^2 > 0.4$ are in bold.

		Africa	Europe	Asia	Whole America	Tropical America	Temperate America
Res_{tot}	b	1.93	0.42	0.32	−0.36	−2.03	0.55
	a	4.92	2.12	2.81	3.29	2.78	1.37
	R^2	**0.69**	0.02	0.02	0.00	**0.41**	0.12
	p	**0.00**	0.53	0.72	0.80	**0.01**	0.65
Res_{prot}	b	1.71	−0.39	0.41	−0.37	−2.41	0.77
	a	3.47	3.60	4.03	3.48	3.19	3.00
	R^2	**0.83**	0.02	0.03	0.01	**0.51**	**0.41**
	p	**0.00**	0.56	0.62	0.77	**0.00**	0.36

when latitude was used as the independent factor, total area explained more of the variance in the number of species than the protected area in all cases except of temperate America (Table 3). The correlation of Res_{tot} and Res_{prot} with latitude, L_i, was consistently negative in all cases (Table 3 and Fig. 1). A significant influence of latitude on species richness was, however, recorded only for

Table 3
Parameters c, d and the associated R^2 and p of the dependences $Res_{tot} = c + d * L$ and $Res_{prot} = c + d * L$ of the residuals of species richness, normalized per unit area, on latitude, L, when total area or protected area were used. Values of $p < 0.05$ and $R^2 > 0.4$ are in bold.

		Africa	Europe	Asia	Whole America	Tropical America	Temperate America
Res_{tot}	d	−0.05	−0.04	−0.06	−0.11	−0.04	−0.07
	c	3.48	3.63	4.07	5.15	4.48	3.25
	R^2	0.13	**0.52**	0.19	**0.74**	0.20	**0.65**
	p	0.26	**0.00**	0.19	**0.00**	0.08	0.19
Res_{prot}	d	−0.03	−0.03	−0.05	−0.09	−0.02	−0.06
	c	2.15	5.42	4.95	5.07	4.93	4.53
	R^2	0.11	**0.43**	0.16	**0.64**	0.06	**0.89**
	p	0.28	**0.00**	0.22	**0.00**	0.34	0.06

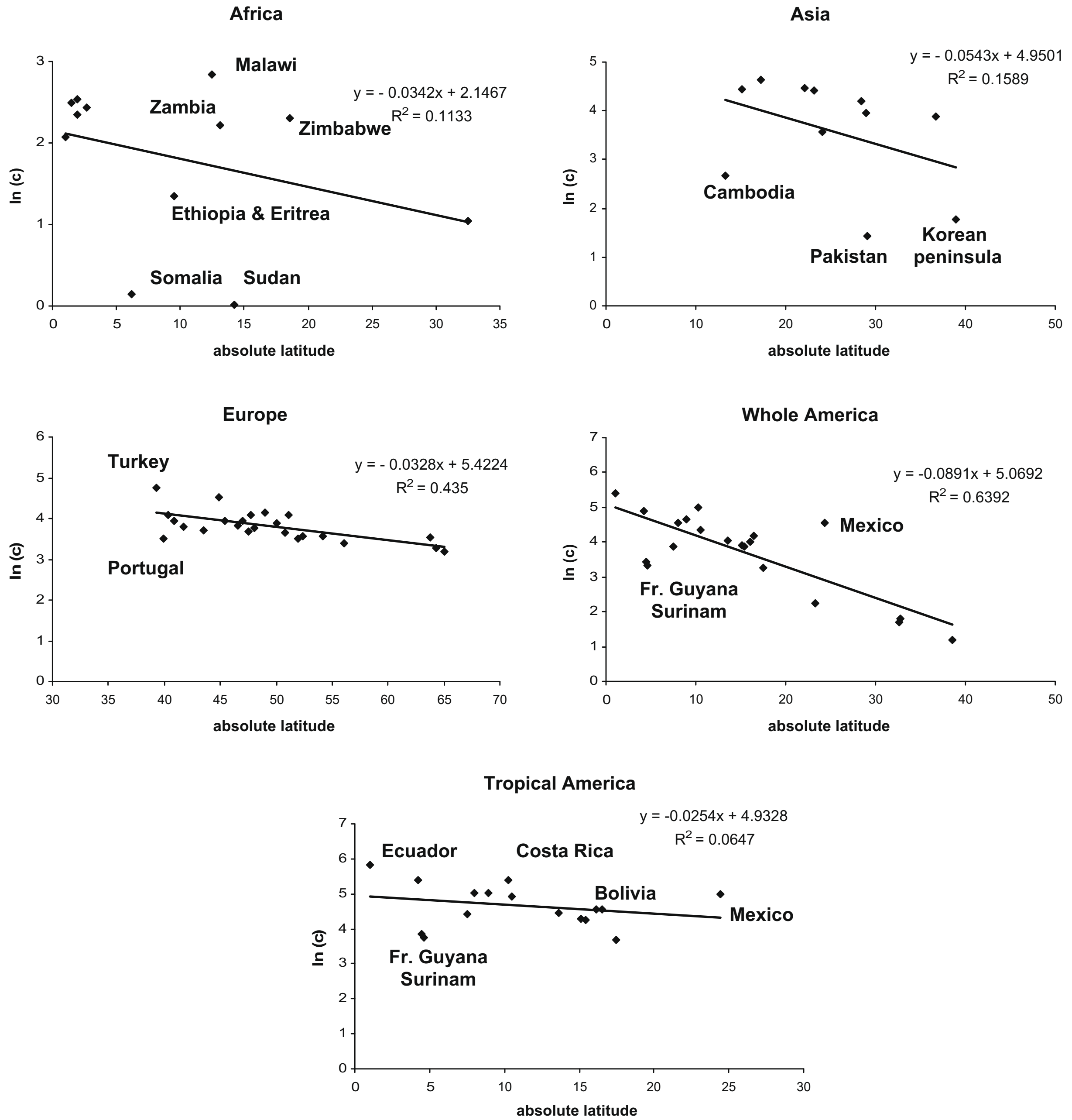

Fig. 1. Relationship between absolute latitude and species richness, after the effect of protected area was removed.

Europe and the whole of the Americas. For Africa and Asia, the outliers (Cambodia, Korean Peninsula, Pakistan and Somalia, Sudan – outside the 5% confidence interval) were likely responsible for the lack of significance (see Fig. 1).

4. Discussion

We aimed to determine which factor best predicts the number of orchid species: total area of the country, size of protected areas of the country, energy available or latitude. Some may assume that protected area is more closely correlated with species richness than is total area. This could be because most countries manage locations with high diversity as reserves or protected areas and the rest of the area consists of an agricultural landscape with a low diversity. This is true especially for orchids. Our data support this for Africa, Asia and North America. However, the reverse was true for Europe and tropical America. The explanation for Europe is that many European orchids thrive in unprotected agricultural meadows and are maintained by regular mowing (Janečková et al., 2006). Other species are confined to forests, which are usually not protected in Europe. In tropical America, only a few countries protect a significant part of their area on this continent: Venezuela (34.4%), Belize (27.5%), French Guyana (14.4%), Surinam (11.3%) and Bolivia (11%); the mean for the remaining countries is 5.3% (The Environmental Information Portal, http://earthtrends.wri.org/searchable_db).

We found a positive correlation between NDVI and number of species only in Africa, but even this may be due to special geographical conditions: two countries with the lowest species richness and NDVI (Sudan and Somalia) are extremely dry, so that most part of their area lacks vegetation and is subsequently uninhabitable for orchids. The low orchid species richness here may also be due to insufficient research due to the political situation.

There is considerable empirical support for a positive correlation between species richness and the energy available (Waide et al., 1999; Mittelbach et al., 2001; Hawkins et al., 2003a,b; Storch et al., 2005). In our case, however, latitude was much better correlated with the residuals of orchid species richness normalized per unit area, Res_{tot} and Res_{prot}, than ln(NDVI). The explanation of the lack of a correlation between ln(NDVI) and Res_{tot}, and between ln(NDVI) and Res_{prot}, may be that on a small scale, energy availability may be important but on a large (continental) scale climate (dependent on latitude) takes priority. The following example may serve as an illustration: more species are expected to be found in a forest than in a meadow at the same latitude, but many more species are found in a tropical forest, compared to a forest at temperate latitudes. The latter dependence overshadows the former. Thus latitude and energy available may be positively correlated (tropical vs. temperate forest), but the lack of a correlation between the amount of energy available and orchid species richness may occur, for example, if energy availability increases towards the tropics more slowly than the number of orchid species.

The positive outliers are Malawi, Zambia and Zimbabwe in Africa and Mexico in America. The negative outliers are Ethiopia and Eritrea, Somalia and Sudan in Africa, Cambodia, Pakistan and Korean peninsula in Asia, and French Guyana and Surinam in South America (see Fig. 1). The reasons for these deviations from the trend may stem from (1) more extreme geographic conditions (e.g., the Ethiopia, Eritrea and Sudan and Pakistan are clearly mostly arid countries); (2) lack of intensive floristic research, which may be the case for Somalia and Cambodia – countries not favoured by orchidologists due to their current or former instability; (3) inverse targeting of specific countries for research: in Europe, where the correlation is very tight, Turkey – a frequent destination of orchid "hunters" – is far above Portugal, which is in a similar latitude, but has a lower orchid diversity. However, this could be an edge effect due to the Atlantic and less stable, oceanic climate. Alternatively, the high species richness as a function of "orchid hunters" could be the result of taxonomic inflation – taxonomic splitting. It would be interesting to explain why Malawi stands out so conspicuously above and French Guyana and Surinam below the regression line. Can topographical variability or the historical past, such as the British pastime of natural history collecting, explain the former and landscape flatness the latter deviation?

5. Conservation implications

One important finding of this paper is that the size of protected areas predicts orchid diversity much better than the total area of the country. This strongly emphasizes the need to maximize the size of protected areas in each country in order to preserve most of its biodiversity. The close correlation between the size of protected areas and orchid species diversity shows that many endangered orchid species might be saved from extinction just by increasing the size of protected areas of suitable habitats and their strict protection. Habitat protection is particularly necessary for plant groups with special habitat requirements, like orchids. Logically, the reverse is also true, any reduction in the size of undisturbed natural areas will necessarily result in extinction of many species, as shown here in the example of the orchid family.

If average temperature is plotted instead of latitude on the *x*-axis, these regressions may serve as a rough prediction, what might happen under the conditions of global change. Our results suggest that the orchid diversity in the temperate regions might increase, but other factors might obscure this prediction. E.g., while this prediction might be correct for South America, it is unlikely to hold in highly industrialized and fragmented landscapes of the northern hemisphere (Europe, North America).

Another aspect of conservation that emerges from our research is the significance of the outliers in our regressions (see Fig. 1). Once the obvious explanations for outliers (i.e., geographic conditions and inverse targeting of specific countries for research) are assigned, then we need to consider whether other countries remaining as outliers do so because they are understudied. This may well be the case for Somalia and Cambodia in Africa and Portugal in Europe. Thus our global analysis of orchid species diversity in various countries can pinpoint understudied countries and direct further research to them. Interestingly, Ecuador and Costa Rica (positive outliers) have many more orchid species per unit area than the less studied Bolivia (on the trend line), even thought all tree countries are in the tropical region and have an enormous altitudinal variation. That the lack of study is the true reason for the relative apparent lack of orchid species in Bolivia was confirmed by Vásquez et al. (2003).

Analyses, similar to those presented here, of other plant and animal groups can guide the efficient allocation of resources to conservation, especially when money is limiting.

Acknowledgements

This research was supported by the Grants LC06073 and MSM6007665801 of the Czech Ministry of Education. D.L.R was funded by the Sarah and Daniel Hrdy Fellowship in Conservation Biology from Harvard University.

Appendix A

Table A1. List of the countries and references.

References	
Africa	
Ethiopia and Eritrea	Demissew, S., Cribb, P.J., Rasmussen, F., 2004. Field Guide to Ethiopian Orchids. Royal Botanical Garden Kew
Kenya	Stewart, J., 1996. Orchids of Kenya. Timber Press Inc.
Kenya, Uganda and Tanzania	IUCN/SSC Orchid Specialist Group (2004)
Malawi	Linder, H.P., Kurzweil, H., 1999. Orchids of Southern Africa, Balkema
Morocco	Raynaud, Ch., 1985. Les Orchidées du Maroc, Société Francaise d́Orchidophilie
Rwanda	IUCN/SSC Orchid Specialist Group (2004)
Somalia	IUCN/SSC Orchid Specialist Group (2004)
Sudan	Andrews, F.W., 1956. The Flowering Plants of Anglo-Egyptian Sudan, vol. 3, pp. 309–325
Zaire	Steward, J., Hennessy, E.F., 1981. Orchids of Africa. The Macmillan Press LTD
Zaire, Rvanda and Burundi	IUCN/SSC Orchid Specialist Group (2004)
Zambia	Steward, J., Hennessy, E.F., 1981. Orchids of Africa. The Macmillan Press LTD
Zimbabwe	Steward, J., Hennessy, E.F., 1981. Orchids of Africa. The Macmillan Press LTD
Asia	
Bangladesh	Huda, M.K., 2000. Diversity, Ecology, Reproductive Biology and Conservation of Orchids of South East Bangladesh Unpublished PhD Thesis. University of Aberdeen
Bhutan	Pearce, N.R., Cribb, P.J., 2002. The Orchids of Bhutan. Royal Botanical Garden Edinburg and Royal Government of Bhutan
Cambodia	Schuiteman, A., de Vogel, E.F., 2000. Orchid Genera of Thailand, Loas, Cambodia & Vietnam. Universiteit Leiden
China	Zenghong, Y., Qitai, Z., Zhizhou, F. Kaiyong, L., Heng, L., 1998. Orchids. Kunming Institute of Botany, Chinese
India	Bose, T.K., Bhattacharjee, S.K., Das, P., Basak, U.C., 1999. Orchids of India (revised ed.). Naya Prokash
Korean Peninsula	IUCN/SSC Orchid Specialist Group (2004)
Myanmar(Burma)	Huda, M.K., 2000. Diversity, Ecology, Reproductive Biology and Conservation of Orchids of South East Bangladesh Unpublished PhD Thesis. University of Aberdeen
Nepal	Rajbhandari, K.B., Bhattarai, S., 2001. Beautiful Orchids of Nepal. Published by Authors
Pakistan	Nasir, E., Ali, S.I., 1984. Orchidaceae, No. 164. Ed: Renz, J.: Flora of Pakistan
Thailand	Schuiteman, A., de Vogel, E.F., 2000. Orchid Genera of Thailand, Loas, Cambodia and Vietnam. Universiteit Leiden
Vietnam	Schuiteman, A. and de Vogel, E.F., 2000. Orchid Genera of Thailand, Loas, Cambodia and Vietnam. Universiteit Leiden
Europe	
Albania	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Austria	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Belgium and Luxembourg	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Bulgaria	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Croatia	Crvenka, M., 1999. Hrvatske Orchideje: Slikovnica Izabranih Kacuna. Inmedia, Zagreb
Czech Republic	Kubát, K., 2002. Klíč ke květeně České republiky, Academia, Praha
Denmark	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Finland	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
France	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Germany	Kreutz, C.A.J., 2002. Feldführer Deutsche Orchideen Langraaf, Netherlands
Great Britain	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Greece	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Hungary	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Italy	Prete, C., Tosi, G., 1988. Orchidee spontanee d'Italia, Mursia, Italy
Netherlands	Kreutz, C.A.J., Dekker, H., 2000. De orchideeën van Nederland. Raalte and Landgraaf, Netherlands
Norway	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Poland	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Portugal	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Romania	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Slovakia	Vlčko, J., Dítě, D., Kolník, M., 2003. Orchids of Slovakia. ZO SZOPK Orchidea, Zvolen
Spain	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Sweden	Flora Europaea, 1980. Alismataceae to Orchidaceae, vol. 5. Cambridge University Press
Switzerland	Reinhard, H.R., Gölz, P., Peter, R., Wildermuth, H., 1991. Die Orchideen der Schweiz und angrenzender Gebiete. Fotorotar AG, Druck and Verlag
Turkey	Kreutz, C.A.J., 1998. Die Orchideen der Türkei. Landgraaf, Netherlands

(*continued on next page*)

Appendix A (*continued*)

References	
Tropical America	
Belize	IUCN/SSC Orchid Specialist Group (2004)
Bolivia	Vasquez, Ch.R., Pierre, L.I., 2000. Orchids of Bolivia – Diversity and Conservation Status, vol. 1. Subtribu: Pleurothallidinae. Editorial F.A.N., Bolivia
Brazil	IUCN/SSC Orchid Specialist Group (2004)
Colombia	IUCN/SSC Orchid Specialist Group (2004)
Costa Rica	Dodson, C.H., Escobar, R., 1994. Native Ecuadorian Orchids I. Hola Colina, Medellin
Ecuador	Dodson, C.H., Escobar, R., 1994. Native Ecuadorian Orchids I. Hola Colina, Medellin
French Guiana	IUCN/SSC Orchid Specialist Group (2004)
Guatemala	IUCN/SSC Orchid Specialist Group (2004)
Guyana	IUCN/SSC Orchid Specialist Group (2004)
Honduras	IUCN/SSC Orchid Specialist Group (2004)
Mexico	Espejo-Serna, A., López-Ferrari, A.R., 1998. Las monocotiledóneas mexicanas una sinopsis florística. 1 Lista de Referencia. Parte VIII. Orchidaceae 2. Consejo de la Flora de México A.C., Universidad Autónoma Metropolitana Iztapalapa, CONABIO. D.F. México
Nicaragua	IUCN/SSC Orchid Specialist Group (2004)
Panama	Dodson, C.H., Escobar, R., 1994. Native Ecuadorian Orchids I. Hola Colina, Medellin
Peru	IUCN/SSC Orchid Specialist Group (2004)
Surinam	IUCN/SSC Orchid Specialist Group (2004)
Venezuela	IUCN/SSC Orchid Specialist Group (2004)
Temperate America	
Argentina	IUCN/SSC Orchid Specialist Group (2004)
Chile	IUCN/SSC Orchid Specialist Group (2004)
Paraguay	IUCN/SSC Orchid Specialist Group (2004)
Uruguay	IUCN/SSC Orchid Specialist Group (2004)

References

Arrhenius, O., 1921. Species and area. J. Ecol. 9, 95–99.

Begon, M., Harper, J.L., Towsend, C.R., 1990. Ecology: Individuals, Populations and Communities, second ed. Blackwell Scientific Publications, Oxford.

Evans, K.L., Greenwood, J.J.D., Gaston, K.J., 2005. The roles of extinction colonization in generating species–energy relationships. J. Anim. Ecol. 74, 498–507.

Flores-Palacios, A., Valencia-Díaz, S., 2007. Local illegal trade reveals unknown diversity and involves a high species richness of wild vascular epiphytes. Biol. Conserv. 136, 372–387.

Forman, R.T.T., 1995. Land mosaics: The Ecology of Landscape and Regions. Cambridge University Press, Cambridge.

Gleason, H.A., 1922. On the relation between species and area. Ecology 3, 158–162.

Hawkins, B.A., Porter, E.E., Diniz-Filho, J.A.F., 2003a. Productivity and history as predictors of the latitudinal diversity gradient for terrestrial birds. Ecology 84, 1608–1623.

Hawkins, B.A., Field, R., Cornell, H.V., Currie, D.J., Guégan, J.F., Kaufman, D.M., Kerr, J.T., Mittelbach, G.G., Oberdorff, T., O'Brien, E.M., Porter, E.E., Turner, J.R.G., 2003b. Energy, water and broad-scale geographic patterns of species richness. Ecology 84, 3105–3117.

Hillebrand, H., 2004. On the generality of the latitudinal diversity gradient. Am. Nat. 163, 192–211.

Jacquemyn, H., Honnay, O., Pailler, T., 2007. Range size variation, nestedness and species turnover of orchid species along an altitudinal gradient on Réunion Island: Implications for conservation. Biol. Conserv. 136, 388–397.

Janečková, P., Wotavová, K., Schödelbauerová, I., Jersáková, J., Kindlmann, P., 2006. Relative effects of management and environmental conditions on performance and survival of population of a terrestrial orchid, *Dactylorhiza majalis*. Biol. Conserv. 129, 40–49.

Kati, V., Devillers, P., Dufrêne, M., Legakis, A., Vokou, D., Lebrun, P., 2004. Hotspots, complementarity or representativeness? designing optimal small-scale reserves for biodiversity conservation. Biol. Conserv. 120, 471–480.

Kerr, J.T., Ostrovsky, M., 2003. From space to species: ecological applications for remote sensing. Trends Ecol. Evol. 19, 299–305.

McDonald, R.I., Kareiva, P., Formana, R.T.T., 2008. The implications of current and future urbanization for global protected areas and biodiversity conservation. Biol. Conserv. 141, 1695–1703.

Mittelbach, G.C., Steiner, C.F., Scheiner, S.M., Gross, K.L., Reynolds, H.L., Waide, R.B., Willig, M.R., Dodson, S.I., Gough, L., 2001. What is the observed relationship between species richness and productivity? Ecology 82, 2381–2396.

Padmawathe, R., Qureshi, Q., Rawat, G.S., 2004. Effects of selective logging on vascular epiphyte diversity in a moist lowland forest of Eastern Himalaya, India. Biol. Conserv. 119, 81–92.

Pelkey, N.W., Stoner, C.J., Caro, T.M., 2000. Vegetation in Tanzania: assessing long term trends and effects of protection using satellite imagery. Biol. Conserv. 94, 297–309.

Pianka, E.R., 1966. Latitudinal gradients in species diversity: a review of concepts. Am. Nat. 100, 33–46.

Possingham, H.P., Wilson, K.A., 2005. Turning up the heat on hotspots. Nature 436, 919–920.

Rohde, K., 1992. Latitudinal gradients in species diversity: the search for the primary cause. Oikos 65, 514–527.

Rosenzweig, M.L., 1995. Species Diversity in Space and Time. Cambridge University Press, Cambridge.

Shriver, W.G., Hodgman, T.P., Gibbs, J.P., Vickery, P.D., 2004. Landscape context influences salt marsh bird diversity and area requirements in New England. Biol. Conserv. 119, 545–553.

Storch, D., Evans, K.L., Gaston, K.J., 2005. The species–area–energy relationship. Ecol. Lett. 8, 487–492.

Ustin, S.L., Wessman, C.A., Curtiss, B., Kasischke, E., Way, J., Vanderbilt, V.C., 1991. Opportunities for using the EOS imaging spectrometers and synthetic aperture radar in ecological models. Ecology 72, 1934–1945.

Vásquez, R., Ibisch, P.L., Gerkmann, B., 2003. Diversity of Bolivian Orchidaceae – a challenge for taxonomic, floristic and conservation research. Org. Divers. Evol. 3, 93–102.

Waide, R.B., Willig, M.R., Steiner, C.F., Mittelbach, G.C., Gough, L., Dodson, S.I., Juday, G.P., Parmenter, R., 1999. The relationship between net primary productivity and species richness. Annu. Rev. Ecol. Syst. 30, 257–300.

Williamson, M.H., 1988. Relationship of species number to area, distance and other variables. In: Myers, A.A., Giller, P.S. (Eds.), Analytical Biogeography. Chapman and Hall, London, pp. 91–115.

Willig, M.R., Kaufman, D.M., Stevens, R.D., 2003. Latitudinal gradients in biodiversity: pattern, process, scale, and synthesis. Annu. Rev. Ecol. Syst. 34, 273–309.

Wilson, K.A., McBride, M.F., Bode, M., Possingham, H.P., 2006. Prioritising global conservation efforts. Nature 440, 337–340.

Wright, D.H., 1983. Species–energy theory: an extension of species–area theory. Oikos 41, 496–506.

Wylie, J.L., Currie, D.J., 1993a. Species–energy theory and patterns of species richness: I. Patterns of bird, angiosperm, and mammal species richness on islands. Biol. Conserv. 63, 137–144.

Wylie, J.L., Currie, D.J., 1993b. Species–energy theory and patterns of species richness: II. Predicting mammal species richness on isolated nature reserves. Biol. Conserv. 63, 145–148.