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Perspective

Trends in conservation biology: Progress or procrastination in a new millennium?

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ABSTRACT

Since the 1990s the number of papers published by four mainstream conservation journals (*Conservation Biology*, *Biological Conservation*, *Biodiversity and Conservation* and *Oryx*) has increased by 133%. The main subject areas of research have not changed over time, with population biology, habitat change, community ecology and species conservation remaining the most popular topics. Equally, mammals, birds, invertebrates and plants have remained the most popular taxa, and – surprisingly – the number of papers dealing with general or global issues or using molecular approaches has remained low. Although collaboration increased over time, most conservation biology is still conducted by researchers working in developed countries. Most research published from developing countries in the 1990s did not have a local researcher as co-author. This trend has now been reversed, although there is only marginal evidence of an increase in collaboration between authors from developed and developing countries. Although conservation science has undergone dramatic technological changes as we have moved into the new millennium, published research remains rooted within the cultural traditions of developed countries, with a continuing emphasis on charismatic taxa.

Contents

1. Introduction

Conservation biology exists as both an academic discipline and as a practical science (e.g. Soulé, 1986; Meine et al., 2006; Sutherland et al., 2009). In an ideal world, the science that emerges from academia should inform conservation practice, but this is not always the case. The reasons for this divide are complex (e.g. Flaspohler et al., 2000; Whitten et al., 2001; Stinchcombe et al., 2002; Smith et al., 2009; Sunderland et al., 2009; Possingham, 2009), but are partly due to the fact that conservation science and conservation practice are driven by different agendas. Funding for these two areas of conservation often comes from different

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donors. This can lead to conservation practitioners believing that scientists are carrying out research that does not meet their needs, while conservation scientists believe that practitioners do not make use of their findings.

The conservation biology literature is dominated by research carried out within academia. Through their editorial policies and practices, the journals that publish this research are important drivers of the direction that conservation biology takes. Although relevance to conservation practice is a goal that many journals aspire to, they are ultimately influenced by other factors such as journal sales, prestige and impact factors. This can lead to research that is cutting-edge and of wide general interest to other scientists, but not necessarily relevant to practical conservation management. On the other hand, there may be threatened species and habitats that require urgent basic research to underpin conservation management. However, such specifically-targeted research may lack the novelty and general interest to warrant publication in an international conservation journal. With careers depending on high-profile publications, the best researchers may lack incentives to carry out such research, or even help build the capacity of others to do so.

Previous research has provided snap-shots of patterns in conservation biology research (e.g. Clark and May, 2002a, 2002b; Fazey et al., 2005a, 2005b; Milner-Gulland et al., 2009). In general, these analyses have shown taxonomic biases towards research on vertebrates, and shortfalls in research from developing countries that have relatively high levels of biodiversity. To our knowledge, only one study has examined temporal trends, and focused on patterns of conservation research on biomes, taxonomic gaps and threats between 1984 and 2004 (Lawler et al., 2006). In this paper we analyse trends in publication in four mainstream conservation journals from 1992 to 2009. To complement earlier work, we focus on (1) whether taxonomic biases have started to be rectified; (2) whether there has been a trend away from regional population/species conservation to more global conservation issues; and (3) whether there is evidence of capacity building in developing countries through collaboration and co-authorship.

2. Methods

2.1. Sampling

We compiled data on publication trends from the following international journals: *Conservation Biology*, *Biological Conservation*, *Biodiversity* and *Conservation*, and *Oryx*. Although these journals embrace a range of different types of publication and editorial policy, they provide a good representation of the global scientific literature in conservation biology. The timeframe for the analyses was dictated by the year in which the most recent of these journals was founded: this was 1992 when volume 1 of *Biodiversity and Conservation* appeared. We then compared trends in the literature published between 1992 and 1995 with that published from 2006 to 2009.

We used the Web of Science to determine the total number of articles published in each journal. As *Oryx* is only included in the Web of Science from 1997 onwards, we manually counted the papers published in this journal before this date. For more detailed analyses we sampled papers from the journals and examined article content. From each journal we randomly selected 10 articles from each year, after excluding book reviews, letters and papers published in special issues that focused on specific taxa, regions or topics. This resulted in a total sample of 320 papers, consisting of 40 papers from each journal per four-year timeframe.

2.2. Subject area

We classified the main subject of each paper into one or more of the following areas: community based conservation, community ecology, economics, habitat change, habitat management, habitat use, population biology, protected areas, species conservation, sustainable resource use, wildlife disease, wildlife law, wildlife trade, conservation education (see Supplementary online appendix for definitions of these categories). We then rexamined those papers that fell into two or more subject areas, and put the subject areas that they covered into rank order of importance using the criteria in the supplementary online appendix. Analyses were based on the highest-ranked subject area for each paper. We also distinguished between papers that had a site, regional or taxon-specific focus from those that dealt with general problems that were of potentially global relevance. Papers were classified as having a site or regional focus if they dealt with a single biotope or ecosystem, or discussed conservation issues that were confined to a single country. Papers were classified as having global relevance if they dealt with multiple biotopes or ecosystems, or issues that were pertinent to countries in more than one geographical region. To assess how technological developments have been embraced within conservation biology, we counted the number of papers that used molecular methods to address conservation issues in each timeframe.

2.3. Taxa studied

For papers that focused on specific taxa we classified the organisms studied into mammals, birds, reptiles, amphibians, fishes, plants, invertebrates, or 'others'. If the article analysed dealt with more general biodiversity issues we classified it as 'general'. We used Spearman rank correlation to examine the relationships between the numbers of papers published on the different taxa and (1) the estimated number of species in each taxon from the 2011 IUCN Red List; and (2) the estimated proportion of threatened species in each taxon. Mammals, birds and amphibians have been completely assessed within the IUCN Red List (http://www.iucnredlist.org/), and plants have been assessed under the IUCN Sampled Red List of Plants (http://www.kew.org/science-conservation/search-rescue/mapping-plants/plants-at-risk/index.htm). The three remaining taxa – reptiles, fishes and invertebrates – have been incompletely assessed or sampled, so the proportions of threatened species were estimated from the 2011 IUCN Red List. We also counted the number of papers that focused on single species and multi-species systems and noted whether the taxon studied was mentioned in the title of the paper.

2.4. Collaboration

We counted the number of authors of each paper, and then classified each author into their continent of origin, based on their institutional affiliation. Additionally, we classified each paper according to the country and continent where the work was carried out, and whether this was a developed or developing country using UN definitions (http://unstats.un.org/unsd/methods/m49/m49regin.htm#developed.). If the article described work that was of global relevance, we placed it into the category 'global' rather than 'developed' or 'developing'.

3. Results

3.1. Number of papers published

The total number of papers published by the four journals increased from 1564 in 1992–1995 to 3644 in 2006–2009. However,

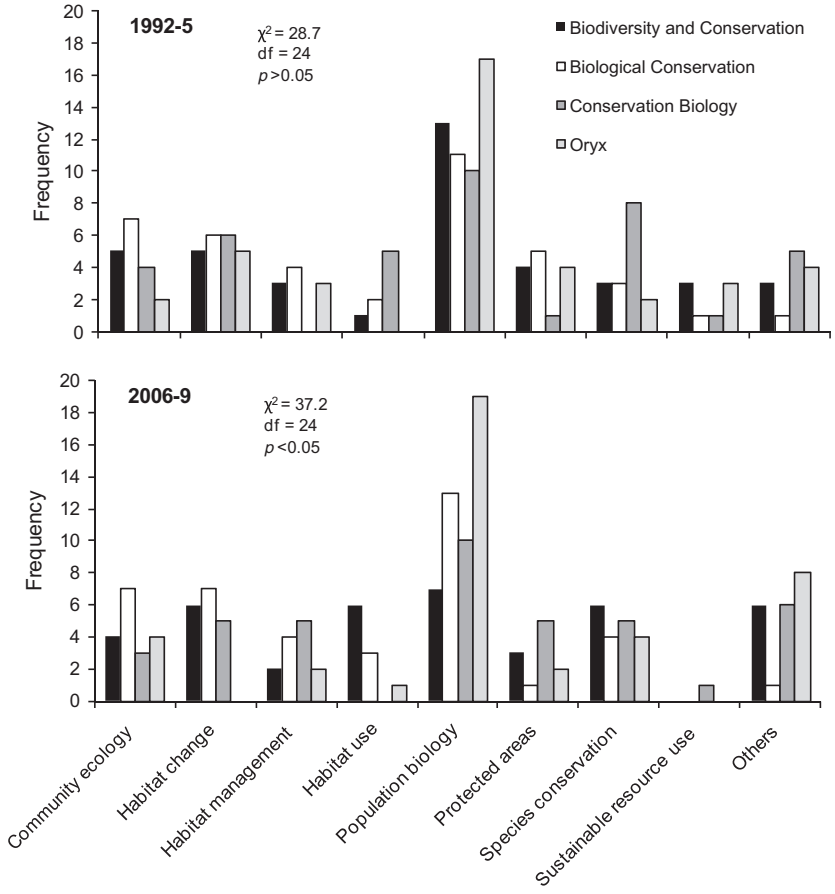

Fig. 1. Number of articles published in different main subject areas in four journals, based on a sample of 160 papers from each time frame. Categories with very low numbers of papers were pooled for analysis and are shown as 'Others' (see Supplementary online appendix for these).

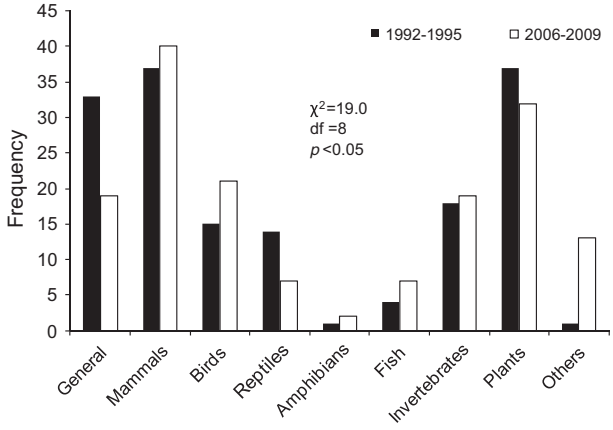

Fig. 2. Number of articles published on different taxa in four journals, based on a sample of 160 papers from each time frame. 'General' refers to papers without a main taxonomic focus, whereas 'Others' are represented by fungi, bacteria and other microorganisms. Pooling amphibians with reptiles (expected frequencies <5) and removing 'General': $\chi^2 = 13.4$, df = 6, $P < 0.05$.

the percentage increase in papers published varied across the four journals: *Oryx* 130%, *Biodiversity and Conservation* 317%, *Biological Conservation* 170%, *Conservation Biology* 37%.

3.2. Subject area

In both timeframes, the main subject area studied was population biology, with habitat change, community ecology and species conservation also popular. Indeed, the subject areas covered did not change between the two time periods ($\chi^2 = 9.0$, df = 8, $P > 0.05$ – pooling some categories to ensure expected frequencies >5). There was a trend for *Oryx* to publish more papers on population biology, but this association between journal and subject area was only marginally significant in 2006–2009 (Fig. 1). Despite the dominance of population biology and species conservation, few

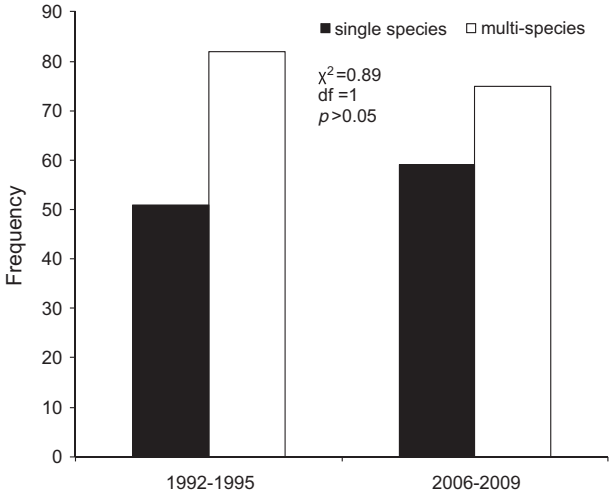

Fig. 3. Number of articles published on single species and multi-species systems in four journals, based on a sample of 160 papers from each time frame.

published studies used molecular methods, and there was no evidence of any changes over time in the use of molecular tools (1992–1995: 12 papers out of 160; 2006–2009: 5 papers out of 160; $\chi^2 = 3.04$, df = 1, $P > 0.05$).

3.3. Taxa studied

There was a strong focus on mammals, plants, invertebrates and birds in both timeframes (Fig. 2). However, there were some small – but significant – shifts in taxa studied, most notably an increase in papers on fungi and microorganisms in recent years. Intriguingly, there appears to have been a decline in papers in recent years dealing with general conservation issues. There was no correlation between the number of papers published and the number of species in each taxon (1992–1995: $r_s = -0.12$, $n = 8$, $P > 0.05$; 2006–2009: $r_s = 0.03$, $n = 8$, $P > 0.05$). Given the uncertainties regarding the number of species in the 'Other' category (i.e. fungi, bacteria and protists) we repeated the test with this category removed but the relationship did not change (1992–1995: $r_s = -0.21$, $n = 7$, $P > 0.05$; 2006–2009: $r_s = 0.04$, $n = 7$, $P > 0.05$). There were also no relationships between the number of papers published and the estimated proportion of threatened species in each taxon (1992–1995: $r_s = -0.58$, $n = 7$, $P > 0.05$; 2006–2009: $r_s = -0.75$, $n = 7$, $P > 0.05$).There were significant differences between the journals in both timeframes, with *Oryx* publishing relatively more papers on mammals than the other journals (1992–1995: $\chi^2 = 52.0$, df = 24, $P < 0.05$; 2006–2009: $\chi^2 = 84.1$, df = 24, $P < 0.05$).

Overall, 34% of papers focused on a single species compared to 49% focusing on multi-species systems. There was no difference between the two time periods in the relative number of papers published on single and multi-species systems (Fig. 3). Equally, three out of the four journals showed no such trend when the data were analysed separately. The exception was *Biological*

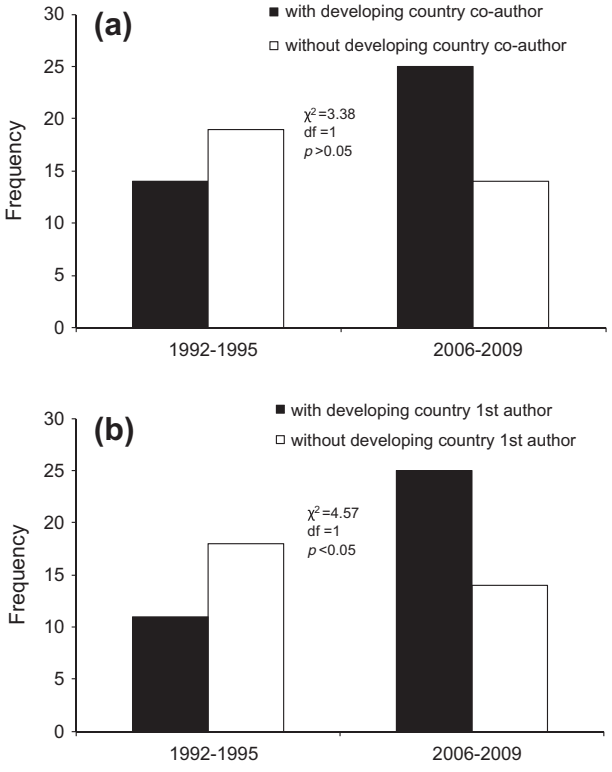

Fig. 5. Collaboration between developed and developing countries based on a sample of 160 papers from each time frame. Data show (a) the number of papers published on research carried out in a developing country that were co-authored by a researcher from that country; (b) the number of papers published on research carried out in a developing country that had a researcher from that country as first author.

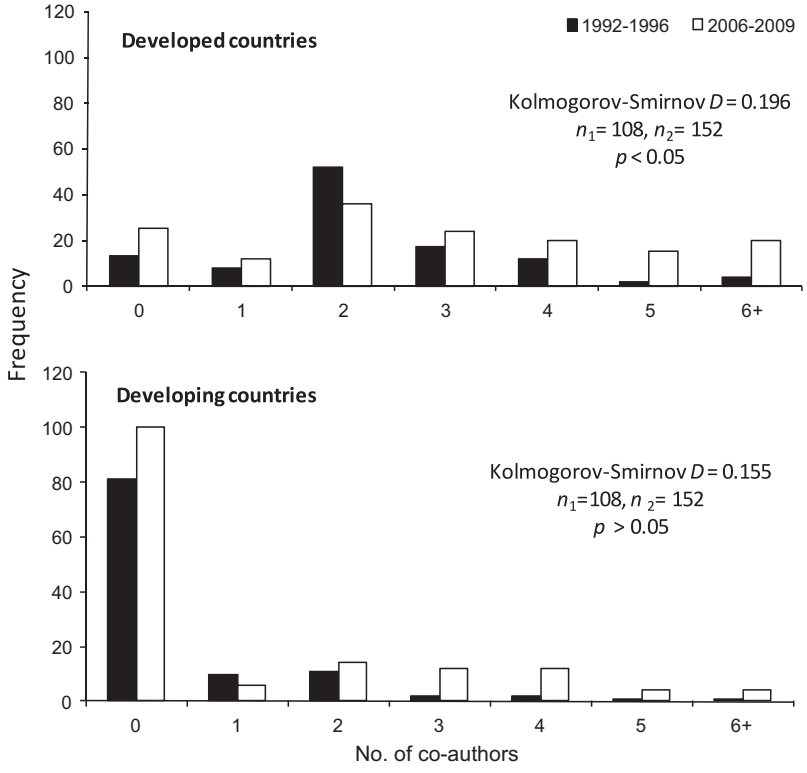

Fig. 4. Number of co-authors from developed and developing countries on papers published with at least dual authorship in the two time frames.

Conservation, which intriguingly published relatively more single species papers in 2006–2009 than it did in 1992–1995 ($\chi^2 = 5.8$, df = 1, $P < 0.05$). Collectively, 56% of papers mentioned the taxon studied in the title of the paper and there was no difference in the tendency to do this between the two time periods ($\chi^2 = 0.12$, df = 1, $P > 0.05$).

There were comparatively few papers that had a primary focus on conservation issues beyond the taxa studied or the site or region in which the work was carried out. For example, only 4% of papers in each time frame had the words 'climate', 'ecosystem', 'landscape' or 'global' in the title. Intriguingly, there was a marginally significant trend for fewer papers with a main focus on global issues in recent years (1992–1995: 19 papers out of 160; 2006–2009: 9 papers out of 160; $\chi^2 = 3.91$, df = 1, $P = 0.048$).

3.4. Collaboration

Collaboration increased over the two timeframes, with the median number of authors per paper increasing from two in 1992–1995 to four in 2006–2009 (Kolmogorov–Smirnov test, $D = 0.41$, n_1 and $n_2 = 160$, $P < 0.001$). The vast majority of collaborations involved authors based in developed countries and working on local or regional conservation issues. Although the number of co-authors from developed countries increased over the same period, there was no corresponding increase in the number of co-authors from developing countries (Fig. 4). Equally, from 1992 to 1995, most research carried out in developing countries did not have a local researcher as a co-author. Although this was no longer the case by 2006–2009, the increase in co-authorship by developing country researchers was not quite significant (Fig. 5). However, there was a slight – but significant – increase in the relative numbers of papers published with the first author from a developing country in the later years.

4. Discussion

Taxonomic biases are widespread within the ecological and conservation literature (e.g. Bonnet et al., 2002; Clark and May, 2002a, 2002b; Stein et al., 2002; Baldi and McCollen, 2003; Pawar, 2003; Trimble and Van Aarde, 2010). Bias can be measured in different ways, but from a conservation viewpoint, perhaps it is most relevant in terms of (1) whether there is disproportionate focus on non-threatened taxa; and (2) a disproportionate focus on certain components of biodiversity (Bonnet et al., 2002). Because so few taxa have been adequately assessed within the Red List, demonstrating bias in terms of threats is problematical in terms of both reliability of the data and statistical power. However, Lawler et al. (2006) examined this issue on the US scale where 95% of taxa have been assessed, and concluded that the most at-risk taxa were those that had been least studied. Our analysis is consistent with this finding, and also showed that mammals, birds, and certain invertebrate and plant groups appear to be over-represented. Despite the growing acknowledgement of biases towards certain taxa and non-threatened species, there is little evidence that the problem is starting to be rectified within the journals reviewed here.

Likewise, conservation science has remained enshrined within population biology, species conservation, habitat change and community ecology over the same period. Given the current trend away from species and population conservation towards more systems based approaches (e.g. Meine et al., 2006; Sutherland et al., 2009), this apparent stability in the type of research carried out is surprising (Indeed, both *Conservation Biology* and *Biological Conservation* currently require submitted papers to be of general interest and to transcend the taxa and system studied). Rather than there being real shifts in the directions that conservation research is taking, the results suggest that authors may well be learning to become more adept at framing their research within wider issues in order to get published. This may be easier to achieve in certain areas than others. For example, Bonnet et al. (2002) showed that for papers submitted to ecological journals, a stronger conceptual framework is needed for papers on amphibians and reptiles than it is for mammals and birds. Equally, methodological and sample size constraints associated with rare species research may limit the extent to which certain taxa can address the general interest and scientific rigor criteria of conservation journals. This may accentuate the taxonomic bias (Pawar, 2003). A further factor contributing to the patterns observed may be the recent growth in the number of journals that focus on wider landscape, ecosystem and global issues. Similarly, the increasing number of researchers who use molecular methods to address conservation issues appear to be publishing their work elsewhere. Alternative vehicles for research in these areas may therefore be more attractive than the journals analysed here.

Earlier snap-shot surveys of the conservation literature have highlighted the relatively low number of papers from developing or low-income countries with local researchers as primary authors. For example, Fazey et al. (2005a) reported that 15% of papers published in 2001 had a local primary co-author, while Milner-Gulland et al. (2009) reported that 37% of articles published from 2000 to 2005 had a local corresponding author. There is considerable variation between countries in the acceptance rate of papers submitted to *Biological Conservation*, and authors from English-speaking, developed countries may have a clear advantage (Primack and Marrs, 2008; Primack et al., 2009). Our data show that although there is a trend towards more first-authorship from developing countries, when viewed over a longer timeframe the situation has improved only slightly in recent years.

Building research capacity within countries with high levels of biodiversity is frequently highlighted as a global conservation priority (Barnard, 1995; Brito and Oprea, 2009). Central elements of capacity building are collaborative research, knowledge exchange and training (Sunderland et al., 2009; Smith et al., 2009). Although there have been more papers published with a first author from a developing country in recent years, collaborations between developed and developing countries are poorly reflected within the primary conservation literature. Indeed, as far as the four journals considered here are concerned, conservation science follows the agendas set by developed countries. Of course, this does not mean that conservation science is not flourishing in the developing world. On the contrary, there has been a proliferation of specialist and regional journals in recent years that are providing vehicles for such work. Equally, there is evidence that scientific output from developing countries is actually increasing at a higher rate than it is in developed countries (Holmgren and Schnitzer, 2004). This raises the question of why – with the possible exception of *Oryx* (Milner-Gulland et al., 2009) – such research has been slow to permeate the journals reviewed here? There may be several reasons for this. Firstly, publishing in a mainstream conservation journal may not be a priority for many researchers. There may be strategic, cultural, political, linguistic and logistic reasons why a regional or specialist journal is chosen instead. Secondly, the nature of the research may mean that it is actually more appropriate for it to be published in a regional or specialist journal. This may be because the research is targeted at a specific – rather than general – conservation audience. Fazey et al. (2005a), for example, showed that a higher proportion of research in low income countries is directly applied to conservation, and Smith et al. (2009) demonstrated that research by government agencies – not academia – was most relevant to conservation implementation. Thirdly, editorial policies and decisions clearly influence the research that is published within constituent journals. Since its inception, the Society for Conservation Biology has attempted to increase its international reach

beyond the boundaries of North America (Meine et al., 2006), and the editorial boards of the journals reviewed here contain a wealth of diversity in terms of experience in developing countries. Nevertheless, there remains a paucity of cultural and ethnic diversity within the membership of these boards. As highlighted by Holmgren and Schnitzer (2004), perceptions of what are the most important and interesting science in prominent journals may be linked to the economic region in which they are based. This can lead to quite different agendas in different parts of the world and different sections of the conservation community (Shine, 1994; Smith et al., 2009).

What lessons can be learned from an assessment of the conservation literature as we have moved into a new millennium? There has been significant advancement in some areas, and surprisingly little advancement in others. Given the diversity of expertise, techniques and approaches needed to address pressing conservation problems, collaborative research is now the norm. The science has evolved, and now embraces sophisticated statistics, molecular genetics, and modelling. On the other hand, conservation biology remains dominated by population and species-level research on charismatic fauna, and is driven by researchers who are mainly academics from developed countries. Although they focused on different variables, our findings are consistent with those of Lawler et al. (2006) who found that the focus of research was in non-priority biomes, less-threatened taxa and less-pressing threats. As Soulé (1986) mused shortly after the birth of the discipline: 'If conservation biology becomes isolated in the mental world of academia, it will be of little use'. Clearly, some further connectivity within the field would be beneficial.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2012.05.011.

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