INTERNATIONAL JOURNAL OF COMPARATIVE PSYCHOLOGY

2014, 27 (1), 101-116
Lance Miller & Heather Hill
Special Issue Editors
Peer-reviewed

Where has all our research gone? A 20-year assessment of the peer-reviewed wildlife conservation literature

Drew T. Cronin, Jake R. Owens, Halle Choi, Steven Hromada, Rumaan Malhotra, and Faith Roser
Drexel University, U. S. A.

Richard A. Bergl
North Carolina Zoological Park, U. S. A.

We conducted a review of the wildlife conservation literature to identify broad trends in the publishing record and focal areas of research over the past 20 years. A total of 5,853 papers were reviewed with an emphasis on decadal changes between 1993, 2002, and 2012. For each paper we identified the journal and common keywords, and also determined the research scope, conservation issues and applications, and geographic focus. We found that both the number of journals publishing in the field, as well as the number of published articles, has increased significantly over time. The proportional contribution of the most prominent journals in the field has decreased over time, but not the importance of the articles within those journals. Previously reported biases in the literature towards mammals and birds, persisted in our study, leaving large proportions of globally threatened taxa (e.g. amphibians) underrepresented. There was also a disparity in the number of publications from particular geographic regions, however, the proportional contribution of under-represented geographic regions (e.g., Central & South America) increased over time. Finally, using the prevalence of keywords, we identified wildlife/adaptive management, hunting/bushmeat, and human wildlife conflict as contemporary (1998-2012) research priorities. The persistence of biases towards charismatic taxa can hinder conservation efforts, and we suggest that researchers refocus their efforts towards vulnerable regions and taxa in order to better address conservation priorities.

The aim of wildlife conservation is to support the preservation of biological diversity in the natural world. Contemporary wildlife conservation is often considered to have its origins in the late 1800's with the creation of the world's first national park (Yellowstone National Park). Wildlife research with a focus on resource management has been conducted since the 1930's, making modern conservation science is a relatively young discipline. The field of conservation biology is generally considered to have its genesis at the First International Conference on Conservation Biology, organized in 1978 by Michael Soulé and Bruce Wilcox (Brussard, 1985). Since then, considerable change has occurred in the research focus and ideological values of conservation biologists. Ultimately, the specific role conservation biology should play in the conservation of wildlife has been debated since the origins of the field (Barry & Oelschlaeger, 1996).

Wildlife conservation is a multifaceted discipline, involving theoretical research in the biological, social, and economic sciences, which is used to inform the development of policy and management actions (Jacobson, 1990). In practice, it has long been referred to as a crisis discipline; often requiring actions or applications before a complete consensus of the research has been met (Soulé, 1985). To be most effective, conservation biologists must address the most pertinent conservation problems, using the most effective and up-to-date methods (Ferraro & Pattanayak, 2006).

There is growing scientific evidence that the explosive growth in human population and the resulting increase in space and resource requirements is driving environmental change at the global scale (Vitousek, 1994). There is significant evidence to suggest we are currently in the early stages of the sixth mass extinction event to occur in earth's history (Wake & Vredenburg, 2008). Of the more than 70,000 species assessed by the International Union for the Conservation of Nature, 21.1% of animals and 55.8% of plants are currently threatened with extinction (IUCN, 2013a). Over the next century, human activities (e.g., anthropogenic climate change, habitat destruction and resource exploitation, emerging infectious diseases, and the invasion of exotic species) are expected to significantly increase the proportion of species threatened, posing a significant threat to both humans and overall biodiversity on a global scale (Sala, 2000). To adequately address the

D. T. Cronin and J. R. Owens contributed equally to this work. Correspondence concerning this article should be addressed to Jake R. Owens, Department of Biology, Drexel University, 3245 Chestnut Street, PISB 503, Philadelphia, PA 19104, (jro35@drexel.edu)

impending biodiversity crisis, conservation biologists must understand the history of the discipline, where the information gaps occur, and be willing to pragmatically evaluate their track record of research and its application (Felton et al., 2009), lest valuable time and resources be inappropriately apportioned.

As noted by Barry and Oelschlaeger (1996), "Practice of conservation biology that does not actively and continuously question the values that shape it is self-defeating." (p. 905). Periodic reviews of scientific literature are a critically important part of this process, providing current information on conservation threats, the status of threatened wildlife, and trends in research (Lawler et al., 2006). Reviews of the conservation literature over the past decade have identified numerous biases in the literature towards certain taxonomic groups, geographic regions, and conservation threats (e.g., Clark & May, 2002; Fazey, Fischer, & Lindenmayer, 2005a,b; Felton et al., 2009; Lawler et al., 2006). Using a qualitative meta-analysis of 5,853 peer-reviewed journal articles published in 901 scientific journals, we evaluated the broad trends within the wildlife conservation literature over the past two decades to assess the status of previously identified information gaps and research biases.

In the current review, we had six primary focal aims. We investigate the general publication record of the wildlife conservation literature, and identified which journals accept studies in this field (Aim 1), and how many articles have published (Aim 2). Second, we identified discrepancies in the relative proportion of studies published on different research scopes (Aim 3), taxonomic classes (Aim 4), conservation issues and applications (Aim 5), and geographic regions (Aim 6). In each of these aims we identified changes in the literature that occurred from 1993 to 2012. Finally, we identified focal topics and research biases from over the past five years, and argue for a reprioritization based on these findings.

Method

We used the ISI Web of Science database to perform a search for peer-reviewed articles that focused on wildlife conservation over the last 20 years (1993-2012). Our search was limited to the exact phrase "wildlife conservation" in the Web of Science "topic" search field, which searches within each article's title, abstract, keywords, and "keywords plus," a series of additional relevant keywords selected by Web of Science editors. The literature search was conducted on August 20th, 2013, yielding 5,903 total articles, of which 50 were excluded as they were judged to have no evident focus on wildlife conservation.

Much of the data used in the analysis, including journal titles, publication year, paper title, citation information, and keywords, were extracted directly from Web of Science. However, we also created a set of subcategories (Table 1) to examine paper contents in greater detail. Each of the papers included in the review were individually evaluated for whether it contained information on one or more of the subcategories. The proportion of articles published by each journal, their citation records, keywords, and each of the subcategories were calculated for each year to assess temporal changes that may have occurred. All temporal changes in publications during the study period were assessed through linear regressions, using statistical software *R* (R Core Development Team, 2013).

We also investigated the representation of different geographic regions in the conservation literature by calculating the change in proportion of studies conducted in 1993, 2002, and 2012 in 12 broad geographic regions (United Nations Statistics Division, 2013), including a "multi-region" category that accounted for any studies that focused on more than one individual geographic region. Proportional representation of a given geographic region was derived by dividing the number of articles from that region by the total number of articles from that particular year. Percent change was then calculated by computing the difference between earlier and later values from a given region. To identify taxonomic biases in the literature over the past five years, we compared the proportional representation of the major taxonomic groups relative to the total number of vertebrate species, as well as vertebrate species threatened with extinction using current estimates from the IUCN Red List (IUCN, 2013a).

To help identify the most current priorities of wildlife conservation research over the past five years, we used the frequency of article keywords from 2008 to 2012. Keywords are chosen by the authors to classify the article within the larger context of the journal's focus, and enable readers and search engines identify its general themes and specific topics. Unlike the previous subcategories we analyzed (Aims 3-6), classification of keywords was not influenced by the questions we sought to answer in this study; thus, they may provide a better approximation of the intended research focus of the authors.

Table 1
Definitions and examples of the article subcategories addressed by studies in the wildlife conservation review

Subcategory	Definition
Geographic Region	World geographic areas defined by the United Nations Statistics Division (UNSD, 2013)
Research Scope	The primary taxonomic or ecological system addressed in the research.
Focal Species	Individual species or comparative analyses of multiple species
Community/Guild	The ecological communities, guilds (organisms that exploit the same class of resources in a similar way), and higher taxonomic levels, including studies of the ecological strategies used by multi-species groups regardless of their phylogenetic relationship or geographic overlap (e.g., long-distance migratory birds)
Ecosystem	A group of ecological communities and the processes therein
Anthropogenic	Studies focused primarily on anthropogenic drivers of, or public perceptions to, conservation threats, or the implications of biodiversity to human livelihoods
Global	Any research addressing world-wide conservation issues
Conservation Issues and Applications	
Applied Conservation	Research methods (e.g., simulations, models, field techniques and survey designs, wildlife forensics), monitoring reports (e.g., wildlife abundance and status; water quality assessments, natural environmental perturbations), and conservation research reviews
Ecology	Any research of the social or behavioral ecology of species
Wildlife Management	Evaluation and implementation of management techniques and concerns (e.g., management and development of reserves, game hunting, balancing consumption and sustainability; controlling fertility, captive breeding, translocation, reintroduction)
Community Conservation	Local opinions of reserves and conservation of wildlife; development of programs including economics, international cooperation, local contributions, education of hunters, locals, etc.
Wildlife Disease	Infectious agents (e.g., parasitism, viral agents) or noncommunicable, chronic maladies (e.g., genetic defects)
Resource Exploitation	Sustainability, bushmeat, fisheries offtake, ivory, and fur industries
Conservation Policy	Public opinion, reviews and analyses on landowner property rights and conservation legislations
Habitat Loss	Effects of fragmentation, deforestation
Invasive Species	Ecological impact, management or monitoring of introduced or invasive species
Climate Change	Any research addressing the general theme of climate change
Public Health	Transmission of wildlife disease to humans
Biodiversity Loss	Effects of species richness and genetic diversity declines on the community or ecosystem
Taxonomic Class Addressed	Mammals, Birds, Reptiles, Amphibians, Fish (Including lampreys and hag fish, sharks, skates, and rays, bony fishes, and coelacanth), Invertebrates, and Plants

Limitations associated with our methods were similar to those detailed in prior conservation reviews. By limiting the study to peer-reviewed scientific journal articles, we were unable to account for the extensive amount of material not published within scientific journals (Felton et al., 2009). Our study also only considered English-language literature, thus research conducted by individuals and institutions outside the English-speaking world was underrepresented (Lawler et al., 2006). Finally, it is important to note that the articles we reviewed only represent a small subset of the total number written about the conservation of animals, as many studies do not include the exact phrase "wildlife conservation" in any of the fields included in the search. Nevertheless, given the generality of the search term, "wildlife conservation", our results should typify a relative sample of overall publishing trends in the field (Felton et al., 2009).

Results and Discussion

Aim 1 & 2: Publishing Record

We found 901 journals that had published 5,853 articles on the topic "wildlife conservation." The number of journals publishing on this topic per year has increased significantly over time ($R^2 = 0.91$, $F(1,18) =$

200.9, $p < 0.001$), more than doubling in number in each of the last two decades (Figure 1). Although focused on a subset of major ecology journals, Lawler et al. (2006) reported a similar trend between 1984 and 2004, indicating that venues for reporting conservation research are continuing to expand. The number of published articles per year has also increased significantly over time ($R^2 = 0.86$, $F(1,18) = 121.1$, $p < 0.001$), at least tripling in number between 1993, 2002, and 2012 (Figure 2).

The 10 journals that published the most articles overall in the field (Table 2) accounted for 31% of the total published articles, while 50% of all articles were encompassed by just 33 journals. A number of journals (8%) in the survey were represented by just one article. *Biological Conservation*, *Biodiversity and Conservation*, and *Conservation Biology* were consistently among the top 10 journals per year publishing wildlife conservation articles, though *Conservation Biology* was not among the top 10 in 2011 and 2012, which may represent a shift in focus, but could also be a by-product of the search term we used. The proportional contribution of the top ten journals in the field has decreased over time ($R^2 = 0.76$, $F(1,18) = 62.15$, $p < 0.001$), concurrent with the growth in the number of both journals and articles published. This further supports the idea that the avenues for publication are diversifying and that wildlife conservation research may be spreading into more specialized journals. The top 10 journals represent 42.8% of the overall number of citations received between 1993 and 2012, though, so although the publishing field may be broadening, the importance of prominent journals in the field has not been diminished.

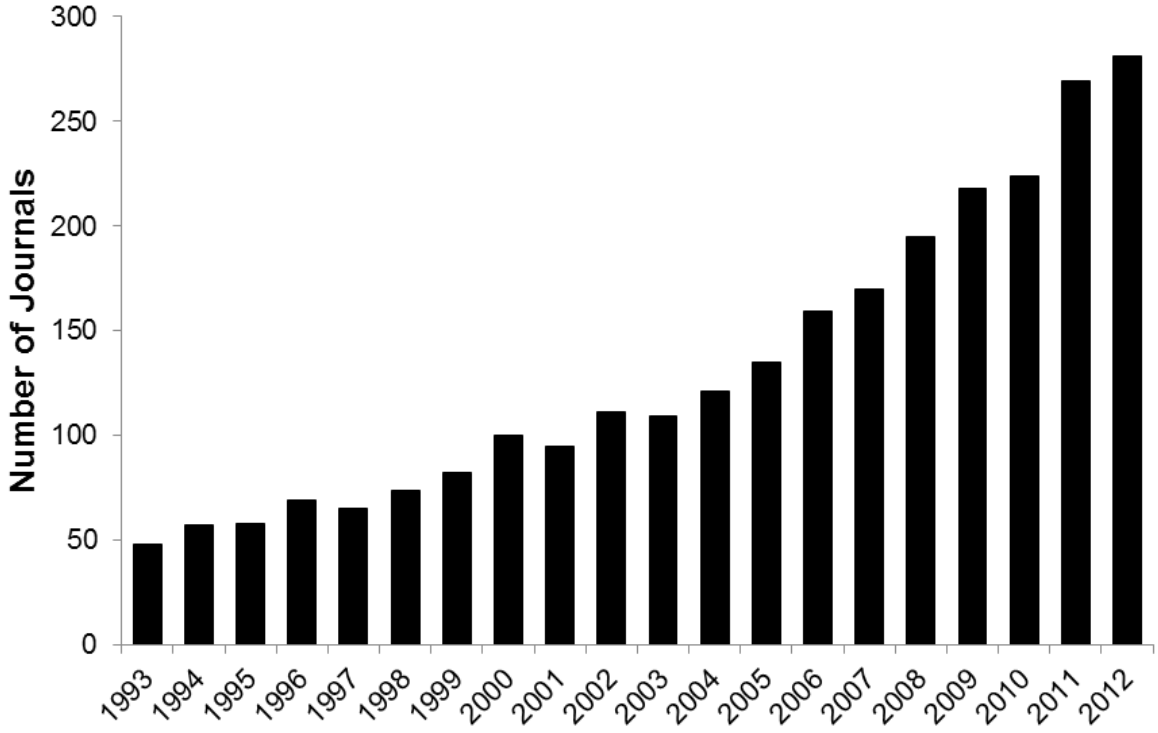

Figure 1. Total number of journals that published articles returned from a search for "wildlife conservation" per year from 1993-2012.

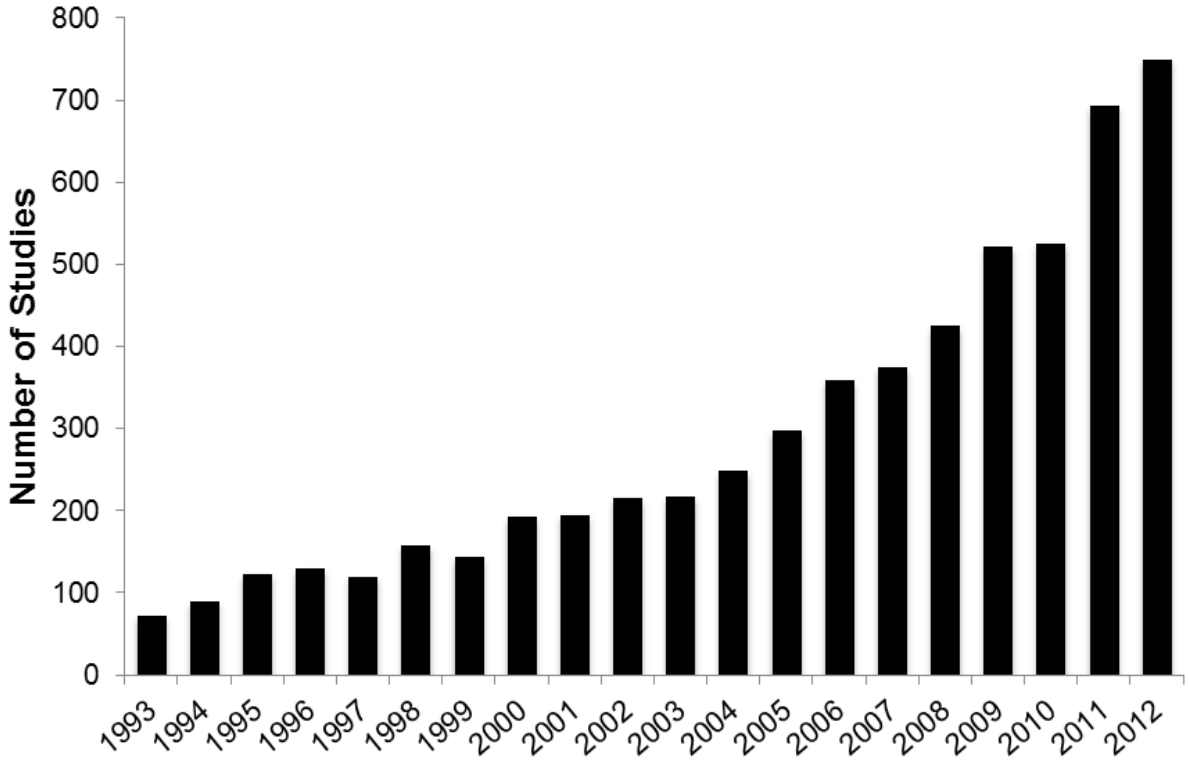

Figure 2. Total number of articles published returned from a search for "wildlife conservation" per year from 1993-2012.

Table 2
Overall top 10 journals based on the number of published articles returned from a search for the phrase "wildlife conservation", and their percent contribution to the total number of articles reviewed between 1993 and 2012

Journal	Total Number of Articles Published	Overall % Contribution
Biodiversity and Conservation	341	5.83
Biological Conservation	309	5.28
Conservation Biology	229	3.91
Environmental Conservation	182	3.12
Environmental Management	176	3.00
Forest Ecology and Management	153	2.61
Journal of Applied Ecology	137	2.34
Journal of Wildlife Management	106	1.81
Oryx	93	1.59
Wildlife Society Bulletin	89	1.52

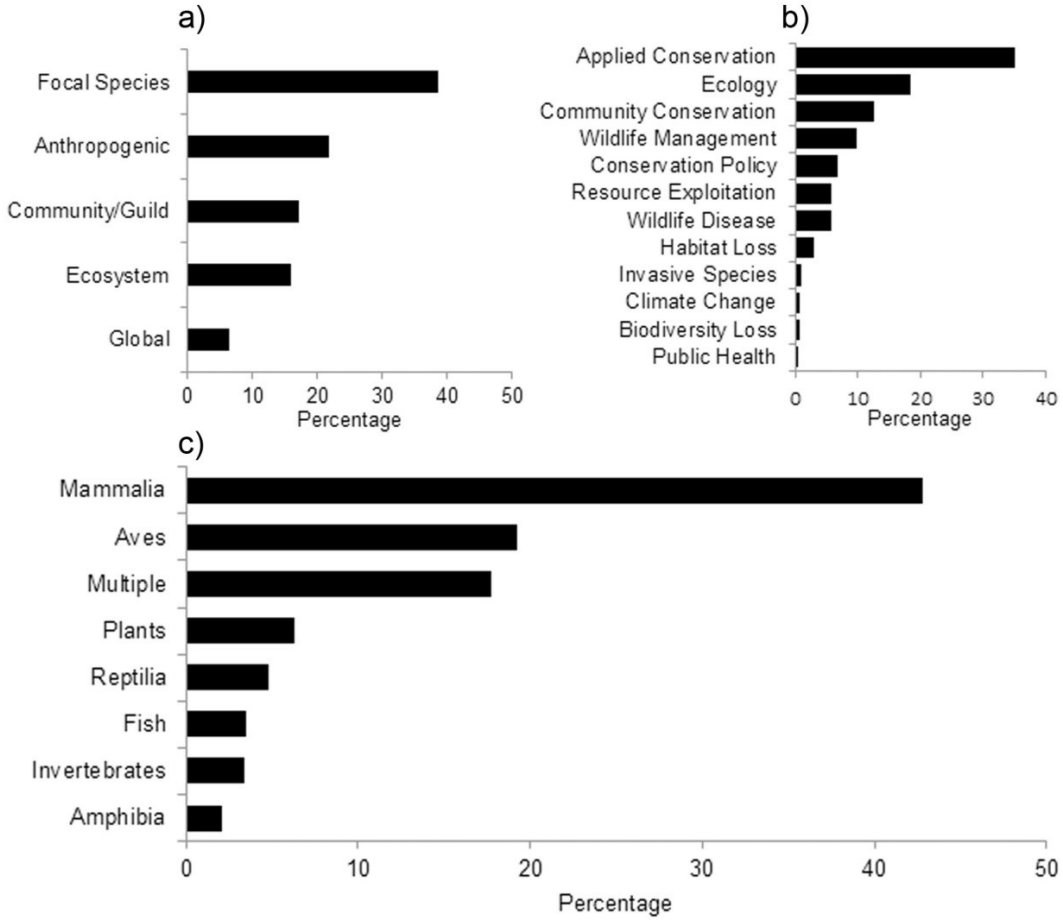

Figure 3. Percentage of all studies categorized by the research scope (a), conservation issues and applications addressed (b), and taxonomic classification (c).

Aim 3: Research Scope

The research focus of 38.7% of articles reviewed was individual species (Figure 3). Analysis of the keywords associated with these articles indicates that birds [i.e., Greater sage-grouse (*Centrocercus urophasianus*), Burrowing owl (*Athene cunicularia*), and Grey partridge (*Perdix perdix*)] and mammals [(i.e., red deer (*Cervus elaphus*), African elephant (*Loxodonta spp.*), bison (*Bison bison*), elk (*Cervus canadensis*)] were the most common study subjects. The large carnivores of North America [i.e., cougar (*Puma concolor*), American black bear (*Ursus americanus*), and grey wolf (*Canus lupis*)] were also frequent topics of research.

This focus on charismatic vertebrates is often linked to the limited financial resources available to conservation programs and the need to strategically allocate resources to maximize impact (Margules & Pressey, 2000; Naidoo & Ricketts, 2006). Conservation projects often focus on certain "flagship" species (i.e., large, charismatic vertebrates) which are used to increase public awareness and financial support for wider biodiversity conservation efforts (Walpole & Leader-Williams, 2002). Birds have also been shown to be effective flagships, as tourists will spend considerable money on birding activities (Veríssimo, Fraser, Groombridge, Bristol, & MacMillan, 2009). The selection of these broadly appealing taxa as research subjects is often motivated by the desire to capitalize on the allure of charismatic vertebrates. However, many of these

species (e.g., large carnivores) also play important roles in the ecosystems they inhabit and act as indicators of environmental problems (Sergio et al., 2008).

While the flagship species strategy is commonly applied, the success of this approach in conservation is difficult to evaluate and can be limited. Several studies have reported increased financial support following the promotion of flagship species (see Sergio et al., 2008), but the impact on conservation success (i.e., reducing threats to biodiversity) is less clear. For instance, tigers (*Panthera tigris*) have been used as a flagship for over two decades, even gaining corporate sponsorship from The Exxon corporation in 1995 (Panthera, 2013). However, this species continues to decline across its range even after 14 years and 17.3 million dollars have been spent on conservation efforts (Rastogi, Hickey, Badola, & Hussain, 2012).

Studies examining the human dimension of wildlife conservation (Anthropogenic category) made up 22.9% of reviewed publications. These were primarily focused on human health and emerging diseases (e.g., Cleaveland, Laurenson, & Taylor, 2001; Daszak, Cunningham, & Hyatt, 2000; Gortázar, Ferroglio, Höfle, Frölich, & Vicente, 2007). Other important topics in the Anthropogenic category included agricultural practices (e.g., Beedell & Rehman, 2000; Hole et al., 2005; Kleijn & Sutherland, 2003), community perceptions of conservation, demography, and involvement in relation to conservation actions or threats (e.g., Berkes, 2004; Brashares, Arcese, & Sam, 2001; Fiallo & Jacobson, 2009), especially in relation to bushmeat hunting practices (e.g., Gibson & Marks, 1995; Brashares, Arcese, Sam, Copolillo, Sinclair, & Balmford, 2004; Wilkie & Carpenter, 1999).

Studies focused on broader scale research (Community/Guild and Ecosystem categories) accounted for 17.2% and 16.0% respectively of publications reviewed. Trends among these articles were harder to identify, and included a diverse array of research topics. The articles most cited in these categories included studies of habitat corridors (e.g., Beier & Noss, 1998), the importance of marine reserves in supporting fisheries (e.g., Roberts, Bohnsack, Gell, Hawkins, & Goodridge, 2001), methodological analysis of techniques to study migratory birds (e.g., Webster, Marra, & Haig, 2002), estimating the value of ecological services provided by insects in the United States (e.g., Losey & Vaughan, 2006), and fish as keystone species (e.g., Willson & Halupka, 1995). Keywords used in these studies indicate that bushmeat hunting, birds, mammals, amphibians, and dispersal were important topics in Community/Guild studies, and forest management, protected areas, habitat fragmentation, and connectivity for Ecosystem studies.

Over the past 20 years, the research scope in wildlife conservation has shifted strongly towards Focal Species studies (Figure 4). The proportion of studies in this category grew from 13% to 61.3%, primarily at the expense of Anthropogenic studies, which made up 40% of the publications in 1993 and declined to 16% in 2012. Studies at the Community/Guild level dropped precipitously in the past two years, from 21% to only 1.6%.

Aim 4: Taxonomic Classes

The majority of the 4,078 studies that addressed a taxonomic group were focused on vertebrates (72.4%), whereas few studies involved plants (6.4%) or invertebrates (3.4%) (Figure 3c). There is no clear consensus of the definition of the term "wildlife," however plants and invertebrates were traditionally not considered wildlife species, although there has been a recent movement towards their inclusion in the definition (Morrison, Marcot, & Mannan, 2006). Thus, many studies of invertebrates and plants might not be included in the results of a literature search of "wildlife conservation." Of the vertebrates, mammals (42.8%), birds (19.2%), and multiple groups (17.8%) were the most prevalent. Less than 200 of the publications in our review were on the conservation of reptiles (4.8%), fish (3.6%), or amphibians (2.1%) (Figure 4). Over the past 20 years these values have fluctuated, but in general the proportions have remained consistent.

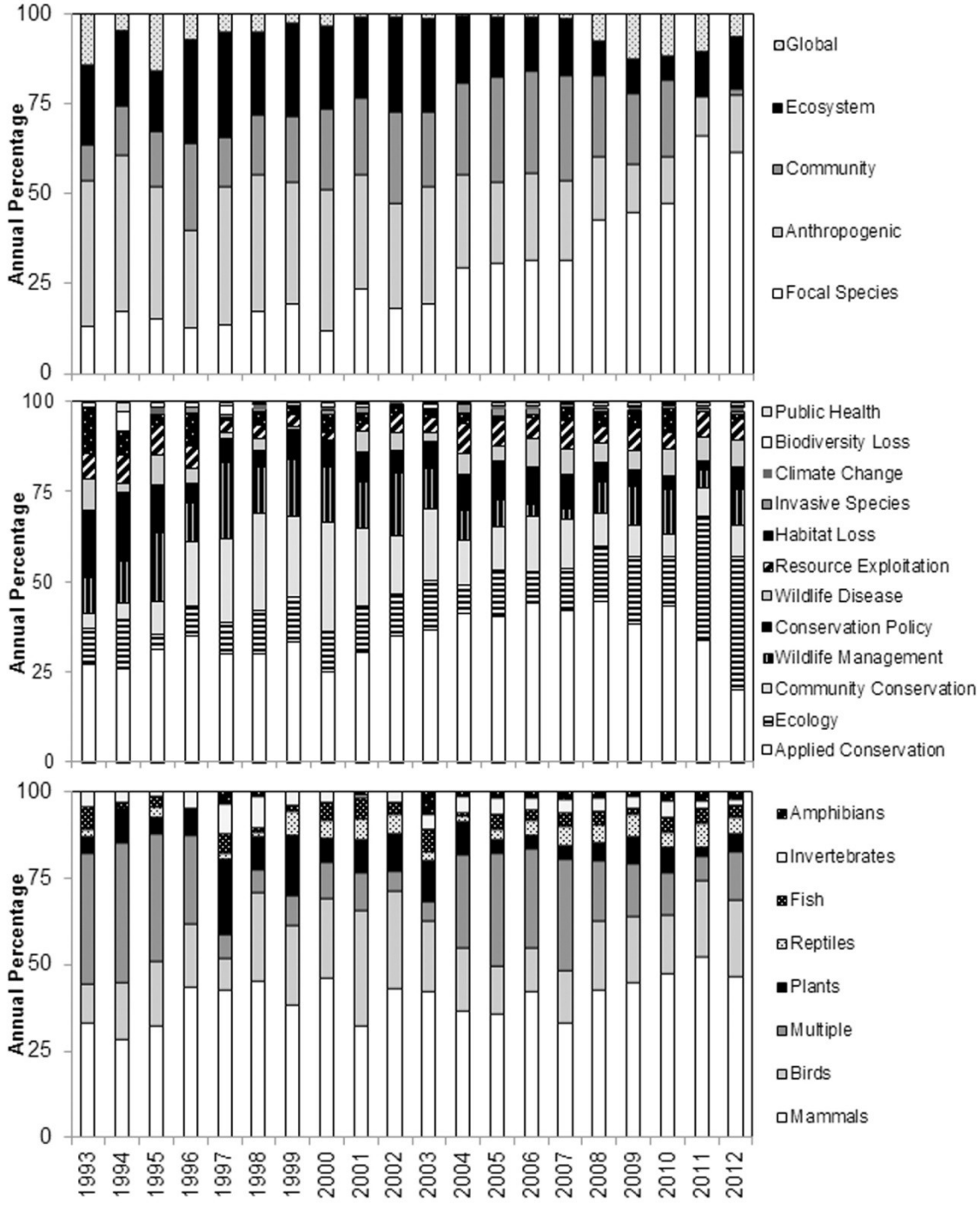

Figure 4. Proportional change in the research scope (top), conservation issues and applications addressed (middle), and taxonomic classification (bottom) in wildlife conservation literature over the past *two decades.*

The overwhelming bias we found towards studies of vertebrates (72%), and mammals and birds in particular (62% combined), is consistent with previous reviews (Báldi & McCollin, 2003; Fazey et al., 2005a; Shine & Bonnet, 2000). In a review of over 2700 articles from two of the leading journals of conservation

research, *Conservation Biology* and *Biological Conservation*, Clark and May (2002) found that in relation to the proportion of the total vertebrate species known, birds (19% of species) and mammals (9% of species) were highly overrepresented in the literature, making up 39% and 40% of all publications. In contrast, fish (48% of species vs. 8% of publications), reptiles (15% vs. 6%), and amphibians (9% vs. 6%) were found to be underrepresented. Lawler et al. (2006) investigated this bias by comparing the number of studies focused on threatened vertebrate species within a taxonomic group to the proportion of species in that group listed as vulnerable, endangered, or critically endangered by the IUCN. They found threatened bird and mammal species to be highly overrepresented in the literature relative to the proportion of taxa threatened (bird: 35% vs. 12%; mammals 27% vs. 20%), whereas amphibians were underrepresented (4% vs. 32%).

Our results were broadly similar to previous reports, with the exception of the ratio of total bird species to bird studies performed (Figure 5). Contrary to previous analyses (Clark & May, 2002) the proportion of bird studies was representative of their prevalence among all vertebrate species (26% vs. 27%). However by both metrics assessed, mammals remained highly overrepresented, and reptiles, fish, and amphibians remain to be underrepresented in the literature.

Aim 5: Conservation Issues and Applications

Publications in the Applied Conservation category made up 35% of the conservation issues or applications addressed in our review (Figure 3). As we noted above, the ultimate goal of wildlife conservation is to preserve biodiversity at every level, from ecosystem and landscape, to species and their genetic makeup (Noss & Cooperrider, 1994). Thus, studies focused on individual species or that had limited applicability to other spatial scales, regions, or conservation threats were infrequently (or never) cited by other articles. Conversely, we found articles with high citation records (over 200) in this category to either provide reviews of the assumptions, applicability, and validity of widely used techniques in the field of wildlife conservation, (e.g., population viability analysis simulation programs, Lacy, 1993; habitat corridors, Beier & Noss, 1998), or those which highlighted major ecological crises (e.g., Chytridiomycosis and rapid global frog declines, Skerratt et al., 2007).

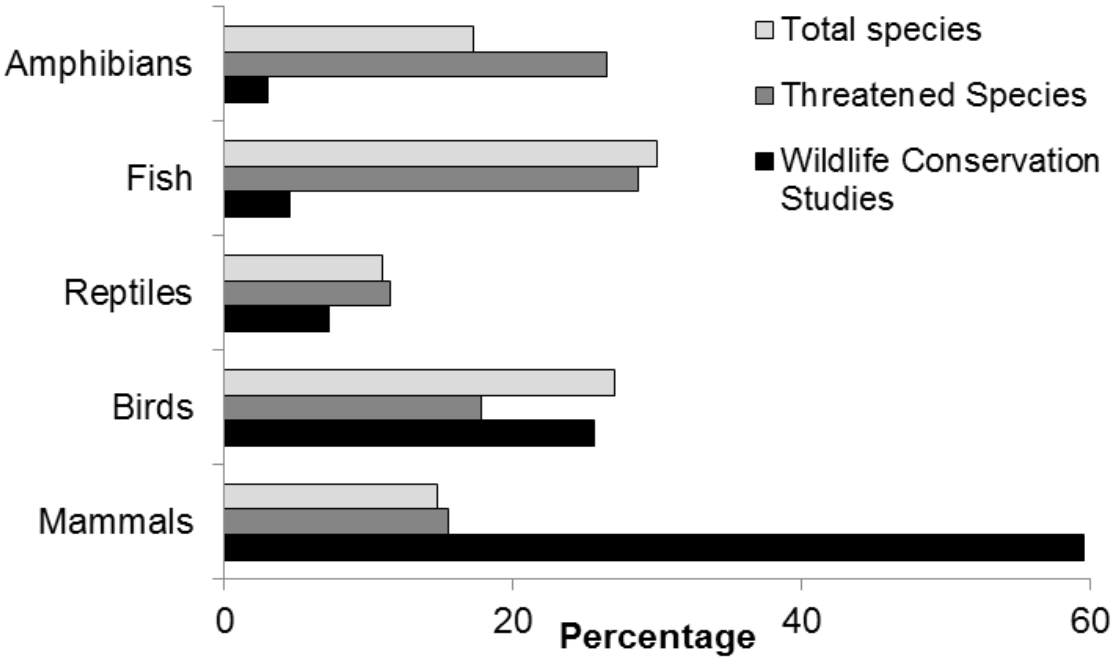

Figure 5. Proportion of each taxonomic class to the total vertebrate species described, total vertebrate species threatened (fishes combined) and their representation in conservation literature from 2008 to 2013.

This trend was particularly true if the articles provided case studies or primary research to assess the validity of prevailing assumptions in the field. For example, in the two most cited articles in our review that addressed Applied Conservation, Fielding and Bell (1997) and Pearce and Ferrier (2000) reviewed aspects of the statistical methods involved habitat-association models, and provided new approaches based on their findings. Habitat association models enable managers to predict the population size, habitat use, and geographic range of species, and are widely applied to a variety of conservation, management, and research initiatives (Guisan & Zimmermann, 2000). In both reviews, the authors detailed the methods used to assess the predictive strength of such models, made explicit recommendations on the applicability and caveats of each method, and provided new methods to fill gaps in the applicability of the previously reported models. The high citation record of these articles (2,282 citations combined), and the extremely wide applicability of the techniques they review, stresses the importance of such broad studies within the literature.

Other subjects in this subcategory we found to be important to the field of wildlife conservation, in terms of their prevalence in the total number of articles we reviewed, included Ecology (18.3%), Community Conservation (12.5%), Wildlife Management (9.8%), Conservation Policy (6.8%), Wildlife Disease (5.7%), and Resource Exploitation (5.7%), together making up 94% of the publications in our review (Figure 3). Surprisingly, Invasive Species and Climate Change were only the focus of 1% and 0.6% respectively of the articles in our review, despite being identified as major threats to global biodiversity (IUCN, 2013b). Over the past 20 years the most apparent changes in this category have been a decline in the focus on Community Conservation, and a recent increase on Ecology, primarily at the expense of Applied Conservation (Figure 4).

Despite the relatively high threat to biodiversity posed by invasive and introduced species (Novacek & Cleland, 2001; Simberloff, 1995), we found a distinct lack of studies of on the topic. This is consistent with other reviews of conservation research (Fazey et al., 2005a), however the relatively low proportion of publications related to climate change (0.6%) was contrary to previous findings. Lawler et al. (2006) reported a significant increase in the publication of climate change studies in conservation literature, from 2% in 1984, to 14% in 2004. Given that there is strong evidence suggesting that the prevalence of invasive species is likely to increase with anthropogenic climate change (Dukes & Mooney, 1999; Occhipinti-Ambrogi, 2007; Vitousek & D'Antonio, 1997; Walther et al., 2009), the absence of these studies in our review is particularly worrisome, but likely related to limiting the search to "wildlife conservation," rather than a real reduction in the number of papers on climate change.

Aim 6: Geographic Regions

Studies were not equally distributed across geographic regions in each of the three years (Figure 6). North America was, by far, the most represented region overall, accounting for 33.14% of the 1,038 total articles in the study published in 1993, 2002, and 2012. The total number of articles with a North America focus also increased by over 650% between1993 and 2012 from 29 to 223, respectively. Conversely, the Arctic and Antarctic (1993: 1, 2002: 1, 2012: 1) and North Africa (1993: 0, 2002: 0, 2012: 1) regions were represented by only a handful of articles in the same time periods and have remained relatively unchanged over time. The largest gains in the numbers of articles in a region were in Southern Asia, the Pacific Islands, and Sub-Saharan Africa, but these are considerably lower than the increase in the number of Multi-Region studies from 7 in 2002, to 140 in 2012.

Despite large increases in the raw numbers of articles originating in almost every region between 1993 and 2012, the proportional representation of many regions behaved much differently. Developed regions (i.e., North America, Europe, and Australia/New Zealand) had the greatest declines, while Southern Asia and Central & South America exhibited the largest gains of individual regions (Figure 6). Lawler et al. (2006) identified that research intensity exceeded conservation priorities in much of the developed world, while research was lacking in Asia, South America, and the Indo-Pacific. They also noted proportional increases in

the number of studies from Central America and declines in Europe between 1984 and 2004. Thus, our data may indicate a continued positive shift in conservation towards a focus on geographic areas identified to be rich in biodiversity, yet understudied and lacking in capacity (Lawler et al., 2006; Felton et al., 2009).

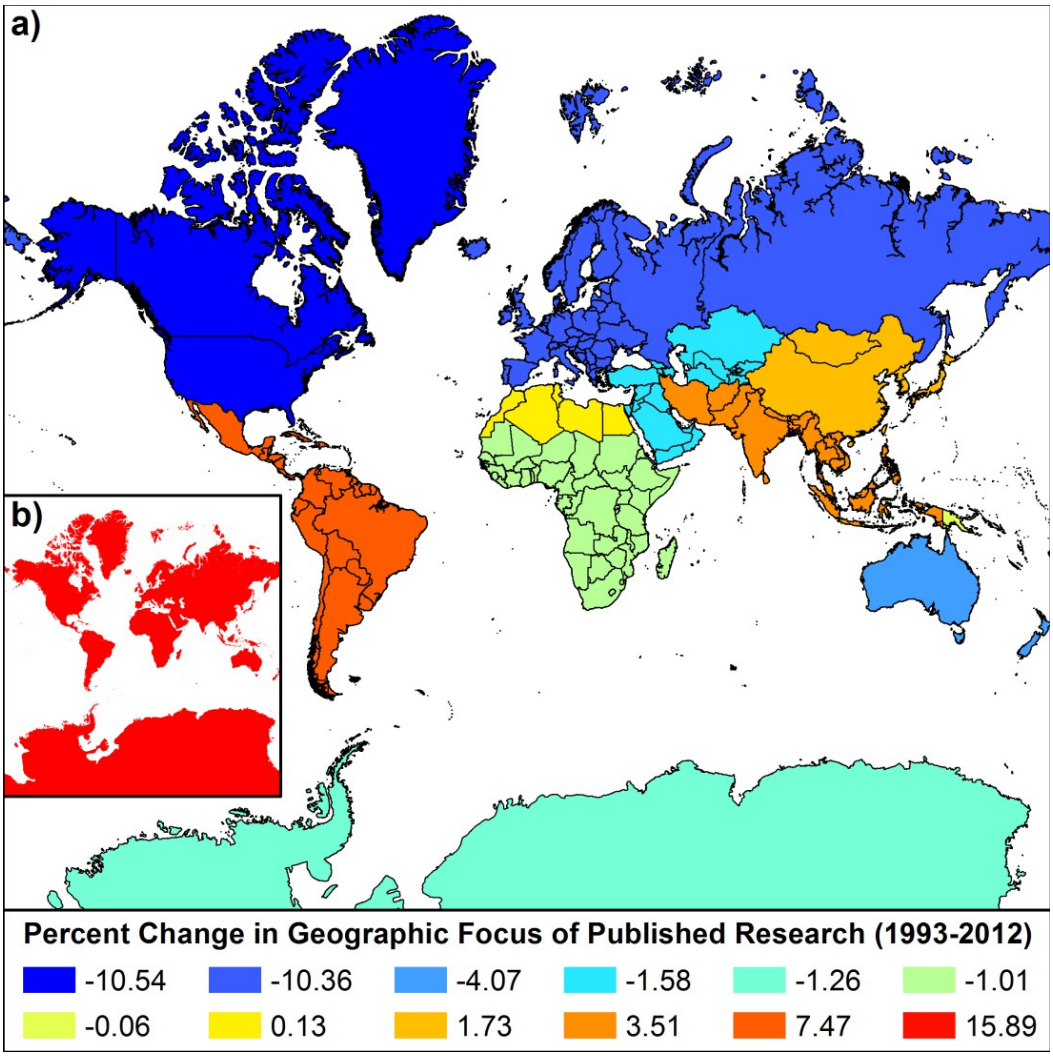

Figure 6. a) Overall proportional change in the number of published articles containing the phrase "wildlife conservation" in the search field that focused on a given geographic region between 1993 and 2012. b) Proportional change in the number of Multi-Region (research focused on >1 geographic region) studies between 1993 and 2012.

The proportional representation of Multi-Region studies also increased by 15.89%, between 1993 and 2012. The ultimate reasons for this are unclear, however in 2012 over 10% of keywords from Multi-Region articles were related to modeling (5.46%) and genetics (4.60%), whereas prior to 2002, these subjects were not referenced by any keywords of Multi-Region studies. The prevalence of these keywords may be related to a number of factors, but the underlying trend suggests that technological and analytical advancements have made it more feasible to focus on broader issues. For example, increasing quality and accessibility of internet access has led to greater access to and development of global data sets, such as WorldClim (Hijmans, Cameron, Parra, Jones, & Jarvis, 2005), as well as spurred development of free and open source modeling software (Steiniger & Hunter, 2013). Moreover, advances in genetic technology in recent years have dramatically increased the amount of potential data available to researchers, as well as the speed at which they can analyze these data, while the cost of acquiring such data continues to decrease (Mardis, 2008; Stapley et al., 2010).

Focus of the Past Five Years

Over the past 20 years, the focus of the wildlife conservation literature has, in general, shifted in concert with the increasingly global nature of threats to biodiversity. There has been an emphasis on broadly applicable research publications and studies at a wider geographic scale. Even the increased proportion of studies on Focal Species is at least partially attributable to efforts aimed at expanding conservation efficacy and efficiency through the promotion of flagship species or similar programs.

Analysis of the keywords used over the past five years helped to further identify research priorities during this period. From 2008 to 2012, 98.1% of the 2,904 total articles contained keywords. As the number included can vary by article, we limited our analysis to the first three provided in each paper. The terms "wildlife" and "conservation" were removed, because they were the search terms used in this review and would be inherently overrepresented in the results. A total of 7,244 unique keywords were tabulated. The most frequently used word in the past five years was "biodiversity", which composed 17% of the top 20 keywords used during this period (Figure 7). Broadly applicable topics such as wildlife/adaptive management (9.7%), hunting/bushmeat (9.4%), human wildlife conflict (5.5%), were also emphasized by the keywords. Within the top 20 most frequent keywords, birds (5.2%) were the only taxonomic group – and India (3.5%) and Africa (3.4%) were the only geographic regions – to be identified.

GIS (global information systems) was the 14th most frequent keyword, associated with 3.6% of articles during this period. GIS mapping software enables users to visualize, manipulate, analyze, and report graphical data, and has become one of the primary tools used in conservation research, planning, and advocacy. Software packages are available for purchase (e.g., ArcGIS from Esri), however an increasing number of projects have developed free or open sourced programs (Steiniger & Hunter, 2013). The importance of GIS in the keywords of the last five years is likely due to recent advances in both the utility and availability of such programs.

Conclusions and Future Directions

It is important to consider these results within the scope of our review methodology. Conservation biology is a broad field, and includes theoretical research, management applications, and the development of policies and laws, and is performed by a diverse set of interested parties. By restricting our literature search to "Wildlife Conservation" we were able to identify some broad patterns within the field, and reveal the depth of subject matter covered, however, it may have excluded certain topics, taxonomic groups, or conservation issues. Future reviews should assess these trends under more broadly and narrowly focused search terms to determine the impact of such scale.

Our broad analysis of the wildlife conservation literature over the past 20 years identified several trends in the focus of research activities in the field. First, there has been a significant expansion of the literature, in terms of both the number of articles published each year and the number of journals publishing articles on the subject. However, the same, small number of journals continue to be most frequently cited, and publish the majority of articles in the field. The disproportionately high impact of these few journals on the broader scope of the literature indicates that the tenfold increase in the number of journals publishing over the past 20 years might have little effect on the focus or efficacy of wildlife conservation as a whole. This is particularly true given that none of the top ten journals are open access, which may inhibit large portions of the conservation community from accessing and using the information published therein.

Second, we found vertebrates, especially birds and mammals, were the focus of the majority of studies with a taxonomic scope, leading to an underrepresentation of invertebrates, plants, fish, reptiles, and amphibians in the literature. These biases have been repeatedly identified by previous reviews, starting more than a decade ago (Clark & May, 2002), yet we found little evidence of an effort to increase the heterogeneity of focal taxa studied. While the diversity of taxa studied has not changed significantly, geographic representativeness has improved somewhat. The proportion of publications from Southern Asia and Central and South America, which had previously been identified as underrepresented in the literature, increased over the past two decades. This indicates that large-scale shifts in the scope and focus of conservation research are indeed possible. Unfortunately, the time to do so is rapidly diminishing. This is particularly true for amphibians, for which the declines or extinctions already reported for an estimated 200 species are likely only a precursor to the numbers expected over the coming century (Skerratt et al., 2007).

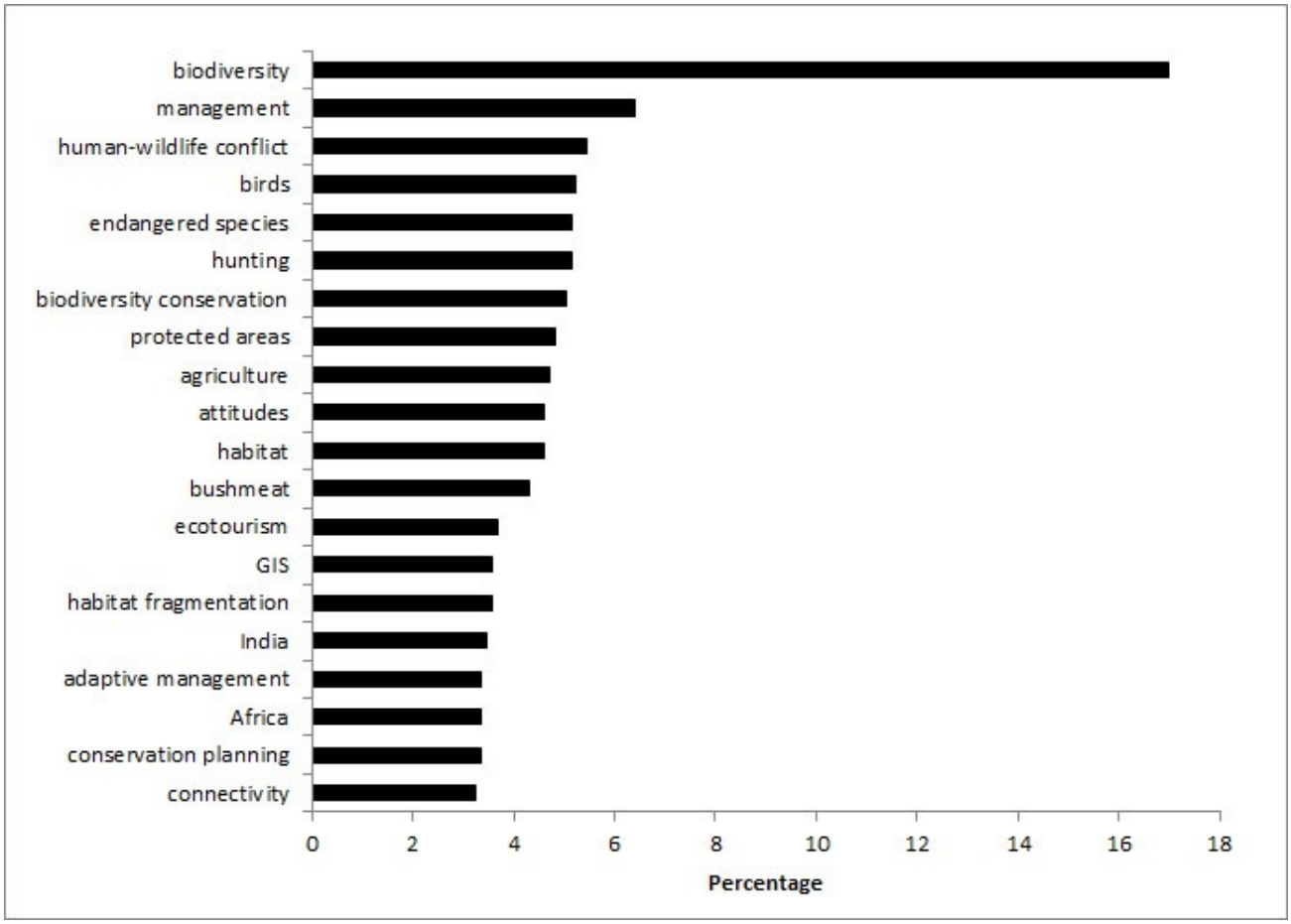

Figure 7. Proportional use of the 20 most frequent keywords in wildlife conservation publications over the last five years (2008-2012).

Our results make a strong argument for the reprioritization of conservation research. Each successive review of the literature has broadened our knowledge of the scope or intensity of the gaps existing in the literature (Báldi & McCollin, 2003; Clark & May, 2002; Fazey et al., 2005a,b; Lawler et al., 2006; Sutherland, Pullin, Dolman, & Knight, 2004), yet we found little evidence of a concerted effort to correct many of these biases. Conservation biology may have come to the point where fundamental changes in the discipline are necessary to meet the challenges posed by the impending biodiversity crisis. We suggest that a critical step in this change is for researchers to prioritize geographic regions and taxonomic groups that are particularly vulnerable and historically underrepresented in the literature.

References

Báldi, A., & McCollin, D. (2003). Island ecology and contingent theory: the role of spatial scale and taxonomic bias. *Global Ecology and Biogeography, 12*, 1-3.

Barry, D., & Oelschlaeger, M. (1996). A science for survival: values and conservation biology. *Conservation Biology, 10*, 904-920.

Beedell, J. D., & Rehman, T. (2000). Using social-psychology models to understand farmers' conservation behaviour. *Journal of Rural Studies, 16*, 117-127.

Beier, P., & Noss, R. F. (1998). Do habitat corridors provide connectivity? *Conservation Biology, 12*(6), 1241-1252.

Berkes, F. (2004). Rethinking community-based conservation. *Conservation Biology, 18*(3), 621-630.

Brashares, J. S., Arcese, P., & Sam, M. K. (2001). Human demography and reserve size predict wildlife extinction in West Africa. *Proceedings of the Royal Society of London Series B-Biological Sciences, 268*, 2473-2478.

Brashares, J. S., Arcese, P., Sam, M. K., Coppolillo, P. B., Sinclair, A. R. E., & Balmford, A. (2004). Bushmeat hunting, wildlife declines, and fish supply in West Africa. *Science, 306*, 1180-1183.

Brussard, P. F. (1985). The current status of conservation biology. *Bulletin of the Ecological Society of America, 66*, 9-11.

Clark, J. A., & May, R. M. (2002). Taxonomic bias in conservation research. *Science, 297*, 191-192.

Cleaveland, S, Laurenson, M. K, & Taylor, L. H. (2001). Diseases of humans and their domestic mammals: pathogen characteristics, host range and the risk of emergence. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 356*, 991-999.

Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife--threats to biodiversity and human health. *Science, 287*, 443–9.

Dukes, J. S., & Mooney, H. A. (1999). Does global change increase the success of biological invaders? *Trends in Ecology & Evolution, 14*, 135-139.

Fazey, I., Fischer, J., & Lindenmayer, D. B. (2005a). What do conservation biologists publish? *Biological Conservation, 124*, 63-73.

Fazey, I., Fischer, J., & Lindenmayer, D. B. (2005b). Who does all the research in conservation biology? *Biodiversity and Conservation, 14*, 917-934.

Felton, A., Fischer, J., Lindenmayer, D. B., Montague-Drake, R., Lowe, A. R., Saunders, D., Felton, A. M., Steffen, W., Munro, N. T., Youngentob, K., Gillen, J., Gibbons, P., Bruzgul, J. E., Fazey, I., Bond, S. J., Elliot, C. P., Macdonald, B. C. T., Porfirio, L. L.; Westagte, M., & Worthy, M. (2009). Climate change, conservation and management: an assessment of the peer-reviewed scientific journal literature. *Biodiversity and Conservation, 18*, 2243-2253.

Ferraro, P. J., & Pattanayak, S. K. (2006). Money for nothing? A call for empirical evaluation of biodiversity conservation investments. *PLoS Biology, 4*, e105.

Fiallo, E. A., & Jacobson, S. K. (2009). Local communities and protected areas: Attitudes of rural residents towards conservation and Machalilla National Park, Ecuador. *Environmental Conservation, 22*, 241.

Fielding, A. H., & Bell, J. F. (1997). A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental Conservation, 24*, 38-49.

Gibson, C. C., & Marks, S. A. (1995). Transforming rural hunters into conservationists: an assessment of community-based wildlife management programs in Africa. *World Development, 23*, 941-957.

Gortázar, C., Ferroglio, E., Höfle, U., Frölich, K., & Vicente, J.(2007). Diseases shared between wildlife and livestock: a European perspective. *European Journal of Wildlife Research, 53*, 241-256.

Guisan, A., & Zimmermann, N. E. (2000). Predictive habitat distribution models in ecology. *Ecological Modelling, 135*, 147-186.

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology, 25*, 1965-1978.

Hole, D. G., Perkins, A. J., Wilson, J. D., Alexander, I. H., Grice, P. V., & Evans, A. D. (2005). Does organic farming benefit biodiversity? *Biological Conservation, 122*, 113-130.

IUCN (2013a). IUCN Red List of Threatened Species. Version 2013.1. Retreived from http://www.iucnredlist.org.

IUCN (2013b). IUCN. Why is biodiversity in crisis? Retrieved from http://www.iucn.org/what/biodiversity/about/biodiversity_crisis/

Jacobson, S. K. (1990). Graduate education in conservation biology. *Conservation Biology, 4*, 431-440.

Kleijn, D., & Sutherland, W. J. (2003). How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology*, *40*, 947-969.

Lacy, R. C. (1993). VORTEX: a computer simulation model for population viability analysis. *Wildlife Research, 20*, 45-65.

Lawler, J. J., Aukema, J. E., Grant, J. B., Halpern, B. S., Kareiva, P., Nelson, C. R., . . . Silliman, B. R. (2006). Conservation science: a 20-year report card. *Frontiers in Ecology and the Environment, 4*, 473-480.

Losey, J. E., & Vaughan, M. (2006). The economic value of ecological services provided by insects. *Bioscience, 56*, 311.

Mardis, E. R. (2008). The impact of next-generation sequencing technology on genetics. *Trends in Genetics, 24*(3), 133-141.

Margules, C. R., & Pressey, R. L. (2000). Systematic conservation planning. *Nature, 405*, 243-253.

Naidoo, R., & Ricketts, T. H. (2006). Mapping the economic costs and benefits of conservation. *PLoS Biology, 4*, e360.

Noss, R. F., & Cooperrider, A. Y. (1994). Saving Nature's Legacy: Protecting and restoring biodiversity. Washington, DC: Island Press

Novacek, M. J., & Cleland, E. E. (2001). The current biodiversity extinction event: scenarios for mitigation and recovery. *Proceedings of the National Academy of Sciences of the United States of America, 98*, 5466-5470.

Occhipinti-Ambrogi, A. (2007). Global change and marine communities: alien species and climate change. *Marine Pollution Bulletin, 55*, 342-352.

Panthera. (2013). *Save the Tiger Fund*. Retrieved from http://www.panthera.org/programs/tiger/save-tiger-fund

Pearce, J., & Ferrier, S. (2000). Evaluating the predictive performance of habitat models developed using logistic regression. *Ecological Modelling, 133*, 225-245.

R Core Team. (2013). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Available from http://www.R-project.org/

Rastogi, A., Hickey, G. M., Badola, R., & Hussain, S. A. (2012). Saving the superstar: a review of the social factors affecting tiger conservation in India. *Journal of Environmental Management, 113*, 328-340.

Roberts, C. M, Bohnsack, J. A, Gell, F., Hawkins, J. P., & Goodridge, R. (2001). Effects of marine reserves on adjacent fisheries. *Science (New York, N.Y.), 294*, 1920-1923.

Sala, O. E. (2000). Global Biodiversity Scenarios for the Year 2100 *Science, 287*, 1770-1774.

Sergio, F., Caro, T., Brown, D., Clucas, B., Hunter, J., Ketchum, J., . . . & Hiraldo, F. (2008). Top predators as conservation tools: Ecological rationale, assumptions, and efficacy. *Annual Review of Ecology, Evolution, and Systematics, 39*, 1-19.

Shine, R., & Bonnet, X. (2000). Snakes: a new 'model organism' in ecological research? *Trends in Ecology & Evolution, 15*(6), 221-222.

Simberloff, D. (1995). Why do introduced species appear to devastate islands more than mainland areas? *Pacific Science*, *49*(1), 87–97.

Skerratt, L. F., Berger, Lee, Speare, R., Cashins, S., McDonald, K. R., Phillott, A. D., . . . & Kenyon, N. (2007). Spread of Chytridiomycosis has caused the rapid global decline and extinction of frogs. *EcoHealth, 4*, 125-134.

Soulé, M. E. (1985). What is conservation biology? *BioScience, 35*, 727-734.

Stapley, J., Reger, J., Feulner, P. G. D., Smadja, C., Galindo, J., Ekblom, R., . . . & Slate, J. (2010). Adaptation genomics: the next generation. *Trends in Ecology & Evolution, 25*(12), 705-712.

Steiniger, S., & Hunter, A. J. S. (2013). The 2012 free and open source GIS software map - A guide to facilitate the research, development, and adoption. *Computers, Environment and Urban Systems, 39*, 136-150.

Sutherland, W. J., Pullin, A. S., Dolman, P. M., & Knight, T. M. (2004). The need for evidence-based conservation. *Trends in Ecology & Evolution*, *19*(6), 305–8.

United Nations Statistics Division. (2013). Composition of macro geographical (continental) regions, geographical sub-regions, and selected economic and other groupings. Retrieved from http://unstats.un.org/unsd/methods/m49/m49regin.htm

Veríssimo, D., Fraser, I., Groombridge, J., Bristol, R., & MacMillan, D. C. (2009). Birds as tourism flagship species: a case study of tropical islands. *Animal Conservation, 12*, 549-558.

Vitousek, P. M. (1994). Beyond global warming: ecology and global change. *Ecology, 75*, 1861-1876.

Vitousek, P. M., & D'Antonio, C. M. (1997). Introduced species: a significant component of human-caused global change. *New Zealand Ecological Society, 21*, 1-16.

Wake, D. B., & Vredenburg, V. T. (2008). Are we in the midst of the sixth mass extinction? A view from the world of amphibians. *Proceedings of the National Sciences of the United States of America, 105*, 11466-11473.

Walpole, M. J., & Leader-Williams, N. (2002). Tourism and flagship species in conservation. *Biodiversity and Conservation, 11*, 543-547.

Walther, G. R., Roques, A., Hulme, P. E, Sykes, M. T, Pysek, P., Kühn, I., . . . & Settele, J. (2009). Alien species in a warmer world: risks and opportunities. *Trends in Ecology & Evolution, 24*, 686-693.

Webster, M. S., Marra, P. P., & Haig, S. M. (2002). Links between worlds: unraveling migratory connectivity. *Trends in Ecology & Evolution, 17*(2), 76-83.

Wilkie, D. S., & Carpenter, J. F. (1999). Bushmeat hunting in the Congo Basin: an assessment of impacts and options for mitigation. *Biodiversity & Conservation, 8*, 927-955.

Willson, M. F., & Halupka, K. C. (1995). Anadromous fish as keystone species in vertebrate communities. *Conservation Biology, 9*, 489-497.

Submitted October 1st, 2013
Accepted December 17th, 2013