Wildlife Research Monographs 1

Rafael Mateo
Beatriz Arroyo
Jesus T. Garcia *Editors*

Current Trends in Wildlife Research

Springer

Wildlife Research Monographs

The book series on “Wildlife Research Monographs” focuses on all aspects of wildlife biology to fill a vital niche at the intersection of several disciplines. The aim of the series is to summarize knowledge about interaction between wildlife species, their habitats, as well as human activities. Main areas are: wildlife ecology, diseases, toxicology, conservation, management, and the sustainable use of natural resources. The series addresses graduate students, university teachers, scientists and professionals.

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Editors

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Foreword

Wildlife is a quite imprecise term for non-domestic organisms, and the taxa included into this group vary across the globe and with time. However, in most areas of the world and during most times, wildlife comprise vertebrates, namely, mammals, birds, and also fish, amphibians, or reptiles. Especially birds and mammals have a quite strong connection to humans. From the emotional point of view, we are attracted or at least fascinated by them, known as biophilia. On the other hand, many wildlife species have difficulties to survive next to humans and their activities; they are endangered and need protection. Some wildlife species have an important role in biodiversity conservation as there are keystone species. Others benefit from anthropogenic environments such as settlements or intensively used arable land. They have to be controlled to minimize damage to human infrastructure, health, or crops. Last but not least, some wildlife species are important for human nutrition, welfare, or even culture. Whatever each wildlife species means to our society, coexistence between man and wildlife deserves management in order to avoid biodiversity loss, to reduce damage caused by wildlife, or to keep wildlife as a natural resource.

However, a sustainable wildlife management needs a sound scientific basis. That is why the demand for wildlife research is growing. Consequently, research activities in scientific fields related to wildlife are increasing exponentially. The quantitative growth is characterized by a qualitative growth, too. While wildlife research was rather descriptive some decades ago, we are now able to follow a hypothesis-driven science. This fascinating development is topped by the fact that wildlife research has a broad spectrum ranging from anatomy to zoonoses and that we have nearly unlimited research avenues using inter- and transdisciplinary approaches.

As the scientific field is growing, there is the need to compile the current knowledge and to sum up the state of the art. Therefore, books like this are an important milestone on our way to find answers to current questions. This book not only provides an overview of what we have learned in the past, it also points to the future and widens our horizon to detect emerging research fields. Thus, the innovative methods and sustainable approaches described here will inspire readers and allow

them to permanently improve quality in wildlife research. In addition, this book offers numerous facets for new ways to increase inter- and transdisciplinarity.

I congratulate the editors and chapter authors of this volume and look forward to see both researchers and students to refer to it as a reference and inspiration.

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Trends in Wildlife Research: A Bibliometric Approach

Beatriz Arroyo, Rafael Mateo, and Jesús T. García

Wildlife Research: Definitions and Concepts

"Wildlife" is a word that has different meanings for different people and in different contexts. In fact, many people use it with an unconscious attachment to a particular meaning, not necessarily aware of it being used differently by other people. According to the Oxford Advanced Learner's Dictionary, wildlife means "*the native fauna* (*and sometimes flora*) *of a region*". In many cases, however, this "native fauna" is, consciously or unconsciously, limited to vertebrate species, and it sometimes excludes fish (as implicitly implied in the names of the "Fish and Wildlife" societies and services in the US). Conversely, fish (at least fresh-water fish) is considered as "wildlife" in many countries, as they are part of the same ecosystems and their management is analogous. Likewise, butterflies and other invertebrates are usually included in "wildlife inventories" at least in the UK. Wildlife is also used as a term for "*undomesticated animals living in the wild*" (American Heritage Dictionary) or "*animals and plants that grow independently of people*, *usually in natural conditions*" (Cambridge Advance Learner's Dictionary & Thesaurus). Here, the emphasis is put in the "untamed" quality of species considered as wildlife. Traditionally, "wildlife" includes all game species in the US, as hunting represents, in the social discourse there, a way to approach wilderness (Good 1997). Indeed, according to the Webster's Dictionary, wildlife means "*wild animals*, *especially those hunted for food or sport*". On the other hand, game species are, at least in Europe, intensively managed, so they do not "grow independently of people", and some voices claim that, in these circumstances, they are livestock rather than wildlife (Díaz et al. 2009). In some European languages, there are different words for game species and non-game species, and only the latter include some reference to

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"wild" in the non-English term (e.g. *faune sauvage* vs *gibier* in French, or *fauna silvestre* vs *fauna cinegética* or *caza* in Spanish). The recent change of name of the "Game Conservancy Trust" in the UK to the "Game and Wildlife Conservancy Trust" somehow also confronts both terms, as if they were, if not antonyms, at least dissimilar or complementary.

Given this variety of meanings, it is equally difficult to define comprehensively and accurately the concept of "wildlife research", without making a too-wide definition like "research made on animals in a natural environment". There exist various scientific journals including the word "wildlife" in the title, many of which launched in North America (even if they have an international scope). These include, among others, the Journal of Wildlife Management, Wildlife Society Bulletin, Wildlife Monographs (all three published by The Wildlife Society in the US), Human Dimensions of Wildlife Management, Journal of Fish and Wildlife Management or the Journal of Wildlife Diseases. Other such journals exist or have appeared more recently in other geographical areas, such as the European Journal of Wildlife Research, Wildlife Research (formerly, Australian Wildlife Research), Wildlife Biology, British Wildlife, the South African Journal of Wildlife Research, or Wildlife Middle-East News. A perusal through those journals indicates that "wildlife research" is used there to refer to studies made with non-captive individuals, usually under an applied optic.

However, these journals do not necessarily encompass all studies about wildlife, or all the possible meanings of the term. Additionally, wildlife research (as many other research disciplines) has also evolved with time, modifying scope and approaches in recent decades. For example, a recent review showed that within the Wildlife Society Journals, there was a trend for an increase in papers related to non-game and multiple species, as well as those including modelling (Powell et al. 2010). Similarly, a similar exercise for papers published in the European Journal of Wildlife Research also showed an increase for papers assessing management or interventions, rather than purely descriptive ones (Gortazar 2012). As research in the field continues to grow, it may be useful to have a broader understanding of its major themes and emerging trends.

We thus aimed to provide an overview of wildlife research that contemplates its variety and changes, even if taking into account that any approach we take is likely to have biases. We opted for a wider bibliometric approach to illustrate trends about wildlife research and identify the most important or emerging research topics within this discipline.

Methods Used

We used the search engine of Scopus. We selected all documents that included the word "wildlife" in the document title, abstract or keywords, or the journal name (*source title* in Scopus) for the period 1984–2013, within Life Sciences, Health Sciences, Physical Sciences or Social Sciences and Humanities. That rendered 51,436 documents.

Within that sample, we looked for the most common specified keywords, using the "keyword" option, in two steps, first for 1984–2004, and then for 2005–2013. This was done to account for the much larger number of papers overall in the last period, and aiming to pick up the maximum possible number of keywords (as the system only shows the 160 most frequent ones). After considering those that were duplicate in both sets, this rendered 186 keywords being mentioned in at least 200 documents each. Of these, 51 referred to either the region or the taxon studied, 14 referred to methods used (e.g. "GIS", or "comparative study" or "animal tissue"), and 12 were not meaningful for the purpose of this review (e.g. "male", "female", "seasons"). The remainder 109 were grouped into categories, revising them step by step and reducing them to main categories when possible (inductive category development; Mayring 2000). This exercise rendered 14 topics, associated to a variable number of keywords (Table 1).

For evaluating the impact of each topic, we restricted the search within Scopus to those documents that contained any of the identified keywords for each topic, thus calculating the number of papers for each topic each year of the study. We subsequently used the citation overview to calculate for each year and topic the total number of citations, and the number of citations within 2 years of publication (e.g., for papers published in 1999, total number of citations up to 2001 included). We then divided this number by number of papers published, to obtain an average number of citations per paper for each topic and year. For identifying milestones in each topic, we searched, within the years where published papers in a particular topic had shown peaks in citations in the subsequent 2 years, those papers that had the highest numbers of citations within that period and assessed their contents. When clear peaks were not noticeable, we identified those papers most cited over periods where citation rate was relatively higher.

For looking at geographical trends, we grouped countries (as mentioned in the keywords) in continents, following the United Nations Statistics Division classification.

Publication Sources

As expected by our search algorithm, a majority (61 %) of the 51,436 identified documents were papers published in a wildlife research journal, with Journal of Wildlife Management and Journal of Wildlife Diseases being the two most important individual journal contributors (Fig. 1). In addition, almost 40 % of identified documents were published in more general journals, mainly journals dealing with applied ecology and management (e.g. Forest Ecology and Management, Journal of Applied Ecology or Environmental Management) or conservation journals (e.g. Biological Conservation, Conservation Biology, Oryx, Biodiversity and Conservation or Environmental Conservation among the most frequent) (Fig. 1). This highlights the fact that wildlife research has indeed a strong applied focus. Wildlife research papers also appeared, although less frequently, in interdisciplinary journals (with PloS ONE, Science and Nature being the most frequent ones).

Table 1 Identified topics in relation to keywords specified in the documents searched

Topic	Keywords
Human actions	Anthropogenic effect; disturbance; ecological impact; environmental impact assessment; environmental impact; human activity; humans; nature-society relations
Biodiversity	Biodiversity; classification; phylogeny; species difference; species specificity
Climate change	Climate change
Conservation	Conservation management; conservation of natural resources; conservation planning; conservation; endangered species; environmental protection; protected area; restoration ecology; species conservation; wildlife conservation
Demography	Abundance; demography; mortality; movement; population decline; population density; population dynamics; population estimation; population size; reproduction; survival
Disease	Animal disease; animal parasitosis; antibodies, bacteria; antibodies, viral; bacteria; bacterium antibody; bird diseases; disease carrier; disease outbreaks; disease reservoirs; disease transmission; drug effect; epidemic; epidemiology; microbiology; parasitology; pathology; prevalence; rabies; unclassified drug; vaccination; virology; virus infection; virus antibody; zoonoses; zoonosis
Ecophysiology	Immunology; metabolism, physiology
Extractive use	Harvesting; hunting
Ecology	Diet; ecology; home range; predation
Genetics	Genetics; nucleotide sequence
Habitat	Agriculture; forest management; forest; forestry; habitat conservation; habitat fragmentation; habitat management; habitat quality; habitat selection; habitat use; habitat; land use; landscape; vegetation; wetlands
Invasive species	Invasive species
Management	Decision making; management; pest control; wildlife management; forest management; habitat management
Pollution	Bioaccumulation; environmental exposure; environmental pollutants; pollution; polychlorinated biphenyl; risk assessment; toxicity; water pollutants, chemical; water pollution; water quality

Geographical Range of Studies

Almost half of the scientific literature about wildlife research published between 1984 and 2013 has been produced in North America (49 %), followed by Europe (26 %), Asia (8 %), Oceania (8 %), Africa (5 %) and Latin America and the Caribbean (3 %) (Fig. 2). Under a temporal perspective, wildlife research had in North America its initial development, and the contribution of publications from this region was predominant until mid-1990s. In this sense, it is worthwhile mentioning the significant contribution of two North American (though now international) scientific societies, The Wildlife Disease Association (publishing The Journal of Wildlife Diseases) and The Wildlife Society (publishing the Journal of Wildlife Management, Wildlife Society Bulletin and Wildlife

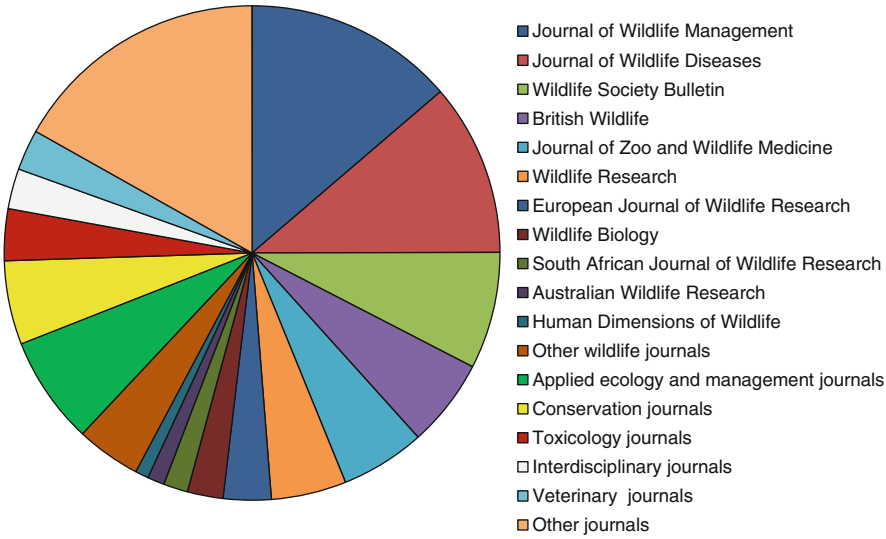


Fig. 1 Proportion of wildlife research papers (n = 51,436) published in different journals

Monographs) as pioneers and leaders in this research field. However, a significant increase in the scientific production on wildlife research in Europe occurred during the 1990s, coinciding with the launch (or restructuring) of two journals, Wildlife Biology (initiated in 1994 by the Nordic Council for Wildlife Research) and the European Journal of Wildlife Research (formerly the Zeitschrift für Jagdwissenschaft, changing name and scope in 1996). Even if the number of wildlife research papers has also strongly increased in North America during that time, the difference in contribution has decreased with time and, in 2013, scientific production in wildlife research from Europe was just 25.3 % lower than in North America (Fig. 2). Other regions have also shown a significant increase in their production, and the sum of Asia, Oceania, Africa and Latin America and the Caribbean represented 30.4 % of the wildlife research literature published in 2013.

Within each region some countries have historically contributed more significantly to wildlife research that others (Fig. 3). In the case of North America, the publications from the United States (84.8 %) exceed by large the production from Canada (15 %). Similarly, in Europe the largest contribution is from the United Kingdom (31.9 %), followed by Germany (9.7 %) and Spain (8.5 %). In Asia, India (22.4 %), China (18.7 %) and Japan (14.3 %) had the greatest contribution to wildlife research in the region. In Oceania, the largest production was from Australia (79.2 %), followed by New Zealand (19.5 %). In Africa, most of the production comes from South Africa (39.3 %), followed by the contribution of Kenia (13.0 %) and Tanzania (7.4 %). In Latin America, Brazil (32.6 %), Mexico (16.7 %) and Argentina (14.8 %) produced most of the wildlife research during our studied period of 30 years.

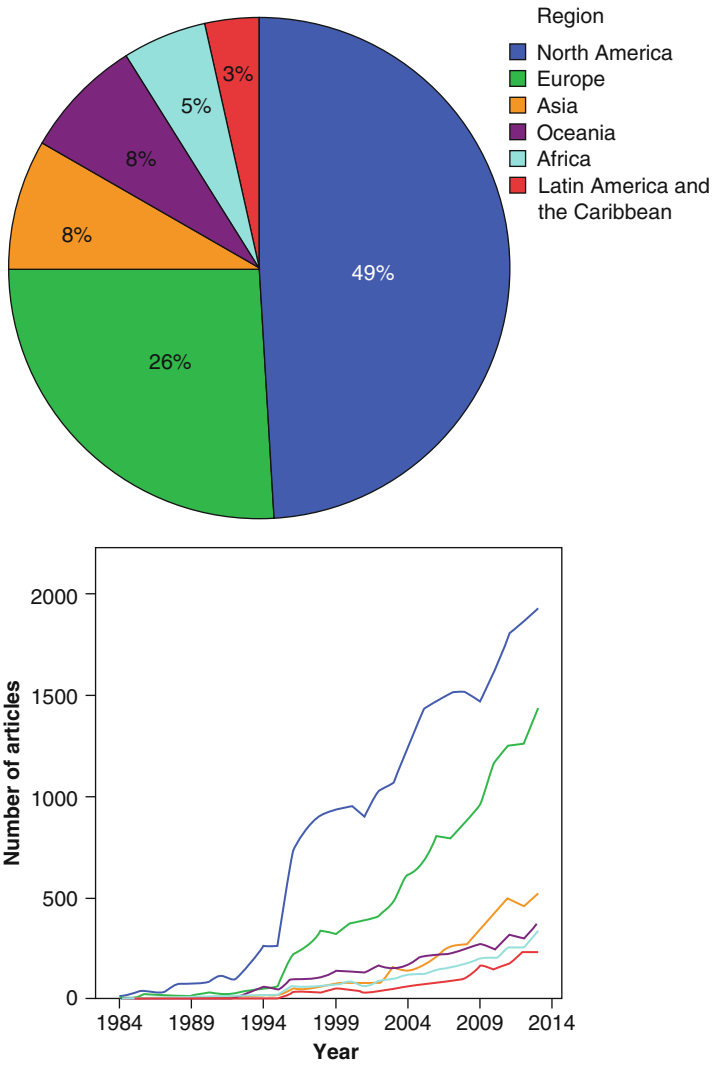


Fig. 2 Total proportion and temporal trends of wildlife research publications in relation to geographical areas

Researched Taxa

Approximately half of the publications (24,049) on wildlife research had some information in their keywords (specific information in 7311 paper keywords) about the taxonomic classification of the species under study. Mammals were the most frequent Class specified in these keywords, followed by birds, amphibians and reptiles. Within mammals, the most frequently studied groups were Cervidae, followed

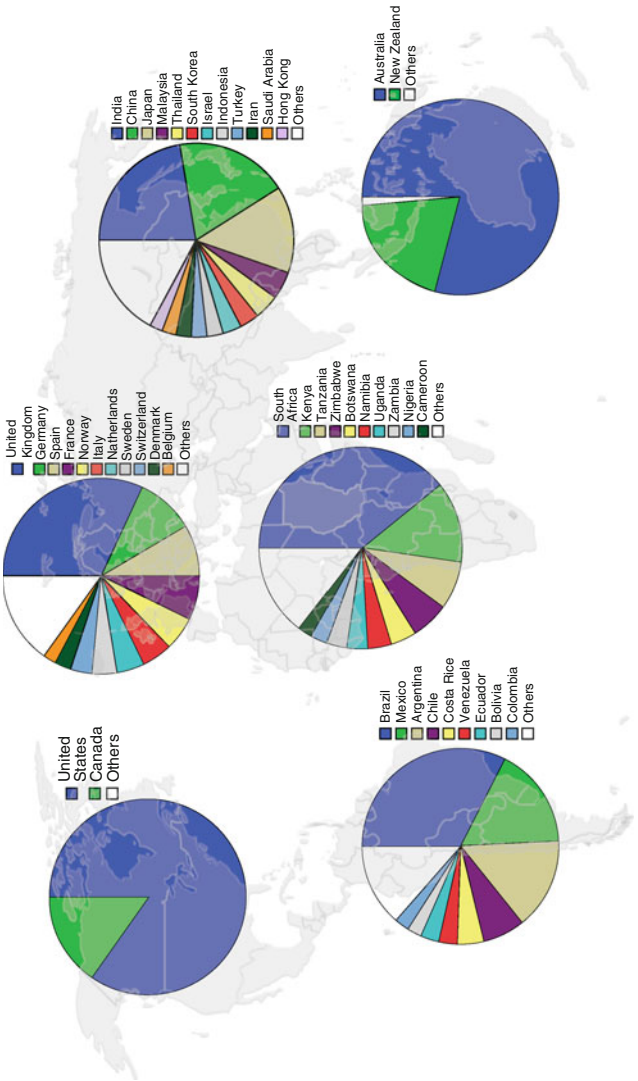


Fig. 3 Contribution of different countries (per continent) to wildlife research publications

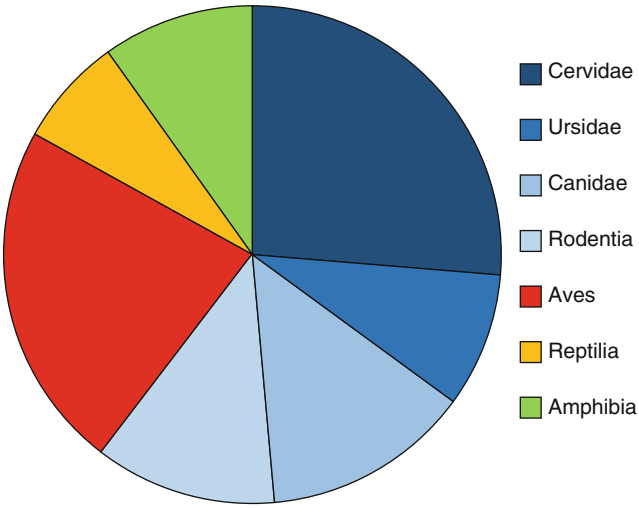


Fig. 4 Proportion of wildlife research studies in relation to studied taxa (for those documents where this was specified in the keywords, n = 24,049)

by Canidae, Ursidae and Rodentia (Fig. 4). This highlights the fact, mentioned above, that there is some bias towards big vertebrates in the approach to wildlife research, and also the focus of either harvested species (such as deer) or conflictive species (both carnivores and rodents) as model studies.

Knowledge Areas

The publications on wildlife research were classified in a total of 27 different knowledge areas, of which nine are the most relevant (Fig. 5), the remainder representing each less than 1 % of all publications. The most important areas are the Environmental Sciences (35 %) and Agricultural and Biological Sciences (31 %). The important presence in Agricultural and Biological Sciences was something expected because of the role of wildlife as a natural resource. On the other hand, the inclusion of wildlife research in Environmental Sciences, as well as in Earth and Planetary Sciences (5 %), denotes that the wildlife concept has a wide application in many areas of research, including those focused in the relationship between humans and the environment. This arises because of the use of wildlife as bioindicator of global issues like environmental pollution or climate change.

Wildlife is also relevant in the areas of Veterinary Sciences, Medicine, Immunology and Microbiology and Biochemistry, Genetics and Molecular Biology. The sum of these areas than can be included in the broader group of Health Sciences represent 16 % of publications under the wildlife research concept. This arises not only from the role of wildlife species as bioindicators, but also

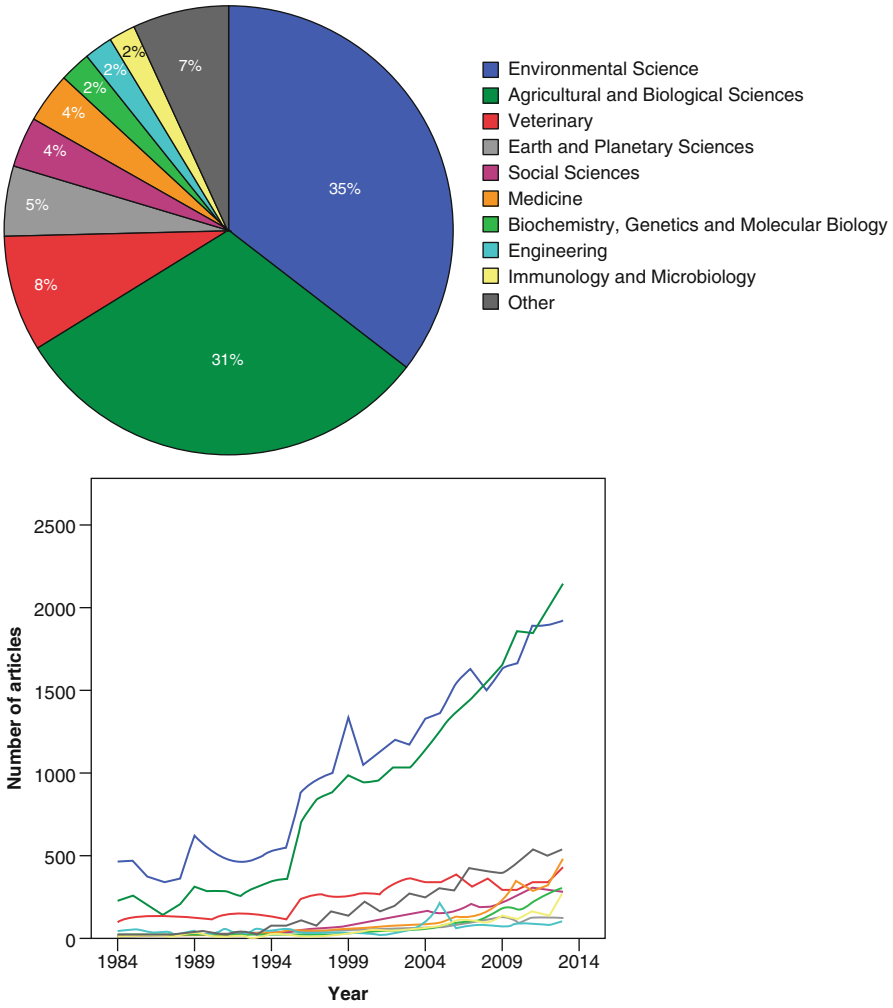


Fig. 5 Total proportion and temporal trends of wildlife research publications in relation to knowledge areas

because of the importance of wildlife as reservoir of infections that can also affect humans and livestock. Finally, the presence of wildlife research in areas like Engineering (2 %) and Social Science (2 %) highlights the relevance of the interactions between humans and wildlife in many aspects of life, like economy, policy and leisure, and the need of applied and technological approaches to face these interactions.

From a temporal perspective, scientific production of wildlife research in Veterinary Science journals has been more or less constant (Fig. 5). In contrast, a sharp increase in wildlife research publications being categorized within Enviromental Sciences or Agricultural and Biological Sciences is evidenced since mid-1990s (Fig. 5). Additionally,

there has been an increase in the last 15 years in a variety of knowledge areas that were initially less important within wildlife research, such as Medicine, Immunology, Microbiology, Biochemistry, Genetics and Molecular Biology. This highlights the fact that wildlife research has shifted in recent decades to incorporate a wider variety of approaches and topics, becoming increasingly multidisciplinary.

Trends of Specific Topics

Indeed, of the 14 topics identified from the keywords extracted from the studied dataset (Table 1), there was a predominance of "diseases" among the topics of the publications in the first years of the studied temporal series, but this has changed through time to a more homogeneous load of the different topics (Fig. 6). Currently "management", "habitat", "disease", "demography", "conservation" and "human activity" have a similar high contribution to publications in wildlife research. This group is followed by "pollution", "ecophysiology", "ecology" and "biodiversity". Topics like "genetics", "extractive use", "invasive species" and "climate change" have currently a comparatively smaller contribution to wildlife research, but their increase has been marked, and their impact is also high (Figs. 7 and 8), so their relative importance may be much higher in the near future. Logically, some of these topics may overlap, and individual publications may contain keywords that we have classified in different topics (e.g. a study on how to control the spread of an emerging disease introduced in the wild by an invasive species may well be included both in "invasive species", "diseases" and in "management"). In any case, these results again highlight the fact that wildlife research studies are interested in a wider variety

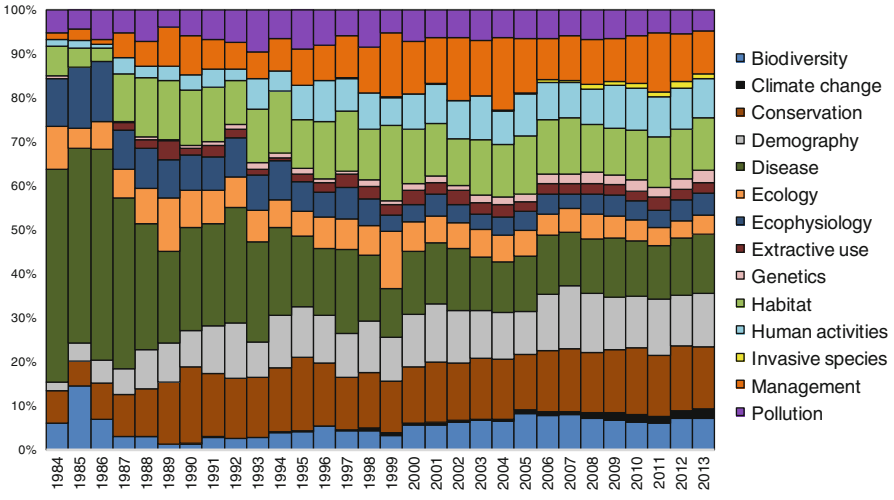


Fig. 6 Proportion of wildlife research publications in relation to topic and publication year

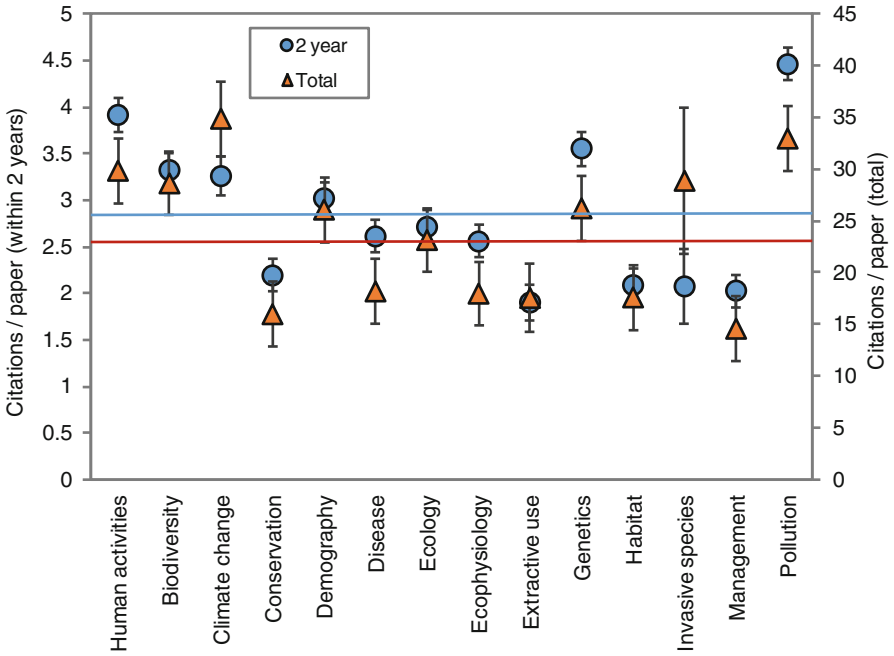
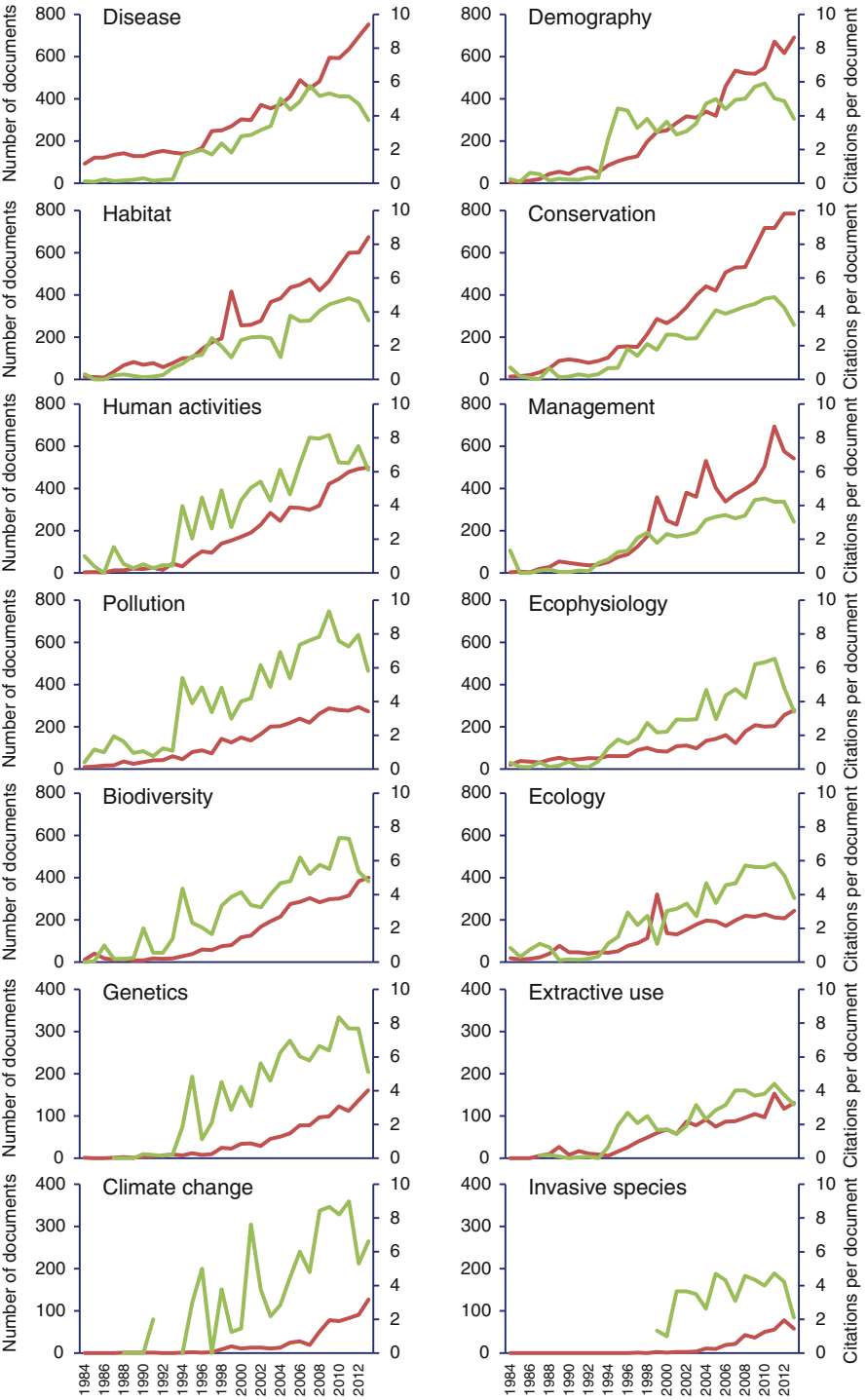


Fig. 7 Average (± SE) citations per paper within 2 years of publication and in total (up to July 2015) for wildlife research publications according to topic. Means calculated as LSMeans from a General Linear Model including "year of publication" as a continuous variable, and "topic" as a categorical variable. Horizontal lines represent the mean for all topics (*in red*, for total citations; in blue, for citations within 2 years of publication)

of issues, and incorporate a wider range of approaches in current times. Multidisciplinarity is thus a marked current trend for wildlife research, as also suggested by the study of scientific impact of different topics.

Scientific Impact by Topic: Trends and Milestones

As in all other disciplines, number of citations per paper has overall increased with time for all topics, in line with the increasing number of papers published (Fig. 8). Taking this overall increase into account, the mean number of citations per paper for studies published during the last 30 years in the area of wildlife research is 2.8 within the first 2 years after publication (i.e. year of publication + 2), and 23.8 in total (i.e., up to July 2015). Five topics had more impact both short-term (within 2 years) and long-term (in total) than the average; these were "pollution", "human activities", "biodiversity", "climate change" and "genetics" (Fig. 7). In addition, the topic of "invasive species" had a strong impact when considering total citations, which is particularly notable considering that most of those papers are relatively


Disease
Demography
Habitat
Conservation
Human activities
Management
Pollution
Ecophysiology
Biodiversity
Ecology
Genetics
Extractive use
Climate change
Invasive species
Number of documents
Citations per document
0
200
400
600
800
100
300
2
4
6
8
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1984
1986
1988
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1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

recent (there were no papers published on this topic before 1997 and regular numbers only appear in the last 10 years, Fig. 8).

Beyond the overall temporal increase in citations, several topics showed marked peaks in the number of citations within 2 years after their publication (Fig. 8), which relate to themes that were timely and relevant and may have helped to increase the visibility of the area at that time. The analysis of the temporal trend of citations together with the number of published papers in each topic permits to outline some of those themes and milestones, which we detail below.

Disease

This topic is one of the most relevant within wildlife research from the beginning, and the number of papers published has increased constantly since the mid-1990s. It showed a remarkable peak of citations in 1995–1996 and then smaller ones in 2004 and 2007 (Fig. 8).

The first citation peak reflected growing interest in wildlife diseases with a zoonotic potential, such as rabies or tuberculosis (O'Reilly and Daborn 1995; Rupprecht et al. 1995), including development of vaccines to prevent some diseases (Ertl and Xiang 1996). Additionally, a study modelling how even moderately severe diseases could increase probability of metapopulation extinctions (Hess 1996) also attracted large attention. In 2004, high impact was partly related to the identification of diclofenac, a veterinary drug used in cattle, as the cause of the decline of Asian vultures (Oaks et al. 2004). Other emerging topics that year leading to high impact of research were the highly pathogenic strain of avian influenza H5N1, not only because of the potential threat for humans, but also by the impact on wildlife conservation (Keawcharoen et al. 2004), and the epidemiology of Ebola virus in wildlife (Leroy et al. 2004). Finally, in 2007 attention was again focused on the role of wildlife in maintaining infections affecting domestic animals or humans (Wolfe et al. 2007; Dubey et al. 2007; Chomel et al. 2007; Gortazar et al. 2007).

Demography

Evaluation of population size, trends and demographic parameters is at the basis of population ecology, and thus wildlife management. The number of papers in this topic within wildlife research is thus large and has increased constantly since mid-1990s (Fig. 8).

Fig. 8 Number of publications (*in red*) and citations per paper within 2 years of publication (*in green*) according to year of publication and topic. Note that the scale for number of publications in the four graphs in the bottom (genetics, extractive use, climate change, invasive species) is different

In terms of citations, it showed a remarkable peak in 1994–1996, and then smaller ones in 2004–2005 and 2009–2010 (Fig. 8). The first one was associated to the publication of papers relating genetic parameters and effective population sizes in wildlife (Frankham 1995c), as well as the effects of contaminants or diseases on reproduction and population declines of wildlife (Facemire et al. 1995; Jobling et al. 1996; Villafuerte et al. 1994). At this time, the concept of virus-vectored contraception as a management tool for wildlife was also in the spotlight (Tyndale-Biscoe 1994). The second one highlights studies on the effects of farming on wildlife declines (Green et al. 2005), and it also picks up those relating the effects on survival or reproduction of pharmaceuticals (Oaks et al. 2004; Nash et al. 2004) or the impact of diseases on population declines (Leroy et al. 2004) already highlighted in other topics. In more recent years, highest impact has been for studies assessing new techniques for estimating population size or habitat-performance relationships (Gaillard et al. 2010; Luikart et al. 2010; Thomas et al. 2010), as well as others highlighting long-term negative fitness effects of captive breeding as a conservation management tool (Araki et al. 2009); impacts of plasticizers (Oehlmann et al. 2009); or the high mortality caused by fungi in amphibians (Harris et al. 2009), which has led to dramatic declines in many places. These examples highlight the transversality of this topic within wildlife research, with regular links to most of the other identified topics.

Habitat

The study of habitat-wildlife relationships is also central to wildlife research, being among the most important numerically at present (Fig. 8). The number of documents dealing with wildlife habitat has increased constantly during the 30-year study period. The marked peak in 1999 was due to the inclusion within this topic of 196 publications of a NCASI Technical Bulletin (a bulletin published by the National Council for Air and Stream Improvement, a non-profit research institute that focuses on environmental topics of interest to the forest products industry) which, that particular year, focused on the relationships between forestry and wildlife.

In terms of scientific impact, some early publications about the importance of habitat fragmentation (Fahrig 1997) and agriculture intensification (Krebs et al. 1999) became influential in the following years. Later, highly cited publications about wildlife habitat dealt with impacts of global changes of land use (Foley et al. 2005; Pickett et al. 2011), and especially with the dilemma of reconciling food production and wildlife conservation and defining appropriate farming strategies (Green et al. 2005; Power 2010).

Conservation

Conservation is also a core topic in wildlife research, with an important and steadily increasing number of papers (Fig. 8). Citation rate has regularly increased, reaching maxima in recent years. Papers highlighted at that time include a variety of themes, reflecting some important current wildlife conservation problems.

For example, papers highlighting the importance of fungus spread for the decline and extinction of frogs worldwide (Skerratt et al. 2007; Kilpatrick et al. 2010) have had strong impact. Conservation problems associated to climate change also feature in this topic (Post et al. 2009; Mawdsley et al. 2009), as well as those associated to other human activities like accumulation of plastic debris (Barnes et al. 2009) or genetic problems associated to harvest or release of plants or animals (Allendorf et al. 2008; Laikre et al. 2010). Also featured are the themes of human-wildlife conflicts (Inskip and Zimmermann 2009), or conservation in urban environments (Goddard et al. 2010). Other studies focus on how to find solutions to conservation problems, including the importance and caveats of assisted colonization or reintroductions to mitigate species extinctions (Seddon et al. 2007; Hoegh-Guldberg et al. 2008); the promotion of citizen science as a tool for conservation (Cooper et al. 2007); or the development of strategies that allow nature conservation and economic development or food production (Tallis et al. 2008; Power 2010). As for demography, these examples underline the transversality of this topic within wildlife research, and the links to most other identified topics.

Human Activities

The number of papers in this topic has been increasing constantly since 1994. Citation rate has been overall high for this topic, but there were marked peaks in the mean number of citations for papers published in the years 1994, 1996, 1998, 2004 and in the period 2007–2010 (Fig. 8).

Many of these high rates of citation are due to publications about environmental pollutants produced as a consequence of human activities. In particular, the peak in 1994 is related to some original and review papers about xenobiotics (i.e. chemical substances found within an organism not normally present there) with endocrine disruption activity, such as polychlorinated biphenyls (PCBs) (Bergman et al. 1994; Bimbaum 1994; Safe 1994). The peak in 1996 also relates to papers considering environmental pollutants because of human activity, but here the endocrine disruptors, including some emerging pollutants like alkylphenol ethoxylates widely used as surfactants, seem to have a leading role (Toppari et al. 1996; Kavlock et al. 1996; Nimrod and Benson 1996; Shelby et al. 1996). This year, research on the effect of human disturbance on animal populations was also on the spotlight (Gill et al. 1996), and had increasing impact subsequently. In the year 1998, research on persistent halogenated pollutants (i.e. dioxin-like compounds) had again a relevant impact due to the development of methods for their risk assessment in humans and wildlife (Van Den Berg et al 1998). More recently, in the period 2007–2010, research on other emerging pollutants originated from a wide range of manufactured products, like the perfluorinated compounds (Lau et al. 2007) or bisphenol A (Wetherill et al. 2007), was still in the focus of researchers, but in this period there was a higher diversity of subjects having high impact: the emergence of new wildlife diseases as a consequence of human actions (Dubey et al. 2007; Chomel et al. 2007); the impacts of biomass production (Semere and Slater 2007); effects of human-induced

climate change in the arctic (Post et al. 2009); environmental impact of plastics (Barnes et al. 2009; Thompson et al. 2009; Oehlmann et al. 2009); impacts on protected species of predator control used for sport hunting (Packer et al. 2009); the adverse effects of widely used herbicides such as glyphosate-based products (Lushchak et al. 2009); or effects on wildlife of infrastructures for energy production or distribution (Kuvlesky et al. 2007; Benítez-López et al. 2010).

Management

As occurs with other broad topics, this one overlaps with many of our identified ones, and the total number of publications including it is elevated. Peaks in the citations of the publications of this topic are, however, not very evident (Fig. 8).

If we focus our analysis on the last part of the study period (2009 and afterwards), we can detect important issues like the transport and release to wildlife of chemical pollution by the plastics present in the environment (Teuten et al. 2009); concepts and methods for the joint analyses of spatial and genetic data (Guillot et al. 2009); the genetic consequences of plant and animal releases (Laikre et al. 2010); the spread of infectious and non-infectious diseases as a consequence of the alteration of global nutrient cycles of phosphorus and nitrogen caused by global changes (Johnson et al. 2010); management plans to cope with climate change effects of biodiversity (Mawdsley et al. 2009) or other types of adaptive management strategies addressed to current challenges (i.e. fire management, food demand) (Driscoll et al. 2010; Phalan et al. 2011). Other ecological aspects less related to human activity have been also on the focus on wildlife management research. In this sense, the perception by prey species of predation risk was found to be important for wildlife population dynamics (Zanette et al. 2011), so the accurate measurement of stress in wildlife was a relevant subject in recent years (Sheriff et al. 2011).

Pollution

The topic of pollution has many similarities with that of human activities in its trend over time (although the overall number of published documents is lower) and in some of the citation peaks. These occurred in 1994, 2002, 2004 and 2009 (Fig. 8).

The peak of citations in 1994 is mostly explained by work on PCBs (Safe 1994) and in particular a paper about their impact on birds from the Great Lakes region (Giesy et al. 1994). By the same time, endocrine disruptors like alkylphenolic compounds used as surfactants were an emerging topic (White et al. 1994). Later in 2002, research on other pollutants like brominated flame retardants (de Wit 2002), alkylphenol ethoxylates (Ying et al. 2002) and other xenoestrogens (Hong et al. 2002; Rajapakase et al. 2002), were of interest for the scientific community. Water pollution with pathogens (i.e *Toxoplasma gondii*) was another issue highlighted in

this topic (Miller et al. 2002). By 2004, high relevance was obtained by some papers about the effect on fish of nanomaterials (i.e. fullerenes) (Oberdörster 2004) or pharmaceuticals such as contraceptive pills (Nash et al. 2004), as well as the mentioned review on brominated flame retardants (Bimbaum and Staskal 2004). Finally in 2009, the relevance is shared among bisphenol A and other endocrine disrupting-chemicals (Diamanti-Kandarakis et al. 2009; Vandenberg et al. 2009), pharmaceuticals (Kümmerer 2009) and plastics (Barnes et al. 2009).

Ecophysiology

The rate of increase in number of papers published in this topic has been more marked in the last 10 years, coinciding with a peak of citations in 2004 and 2009–2011 (Fig. 8).

High impact studies in 2004 were quite diverse, including a review about toxins of plants (i.e. pyrrolizidine alkaloids) (Fu et al. 2004), the application of novel molecular technologies in ecotoxicological studies (Snape et al. 2004), or the use of faecal glucocorticoids (an indicator of physiological stress) in ecological and conservation biology studies (Millspaugh and Washburn 2004). The latter issue (glucocorticoid analyses as a measure of stress in wildlife) was also a highly cited issue later in the period 2010–2011 (Sheriff et al. 2011), as well as the physiological effects of different types of persistent organic pollutants and metals (Chen and Hale 2010; Koivula and Eeva 2010; Letcher et al. 2010) and the global impact of wildlife diseases in the ecosystems (Tompkins et al. 2011).

Biodiversity

The study of biodiversity as part of wildlife research has also increased steadily throughout our study period. The mean number of citations per paper showed a marked peak in mid-1990s, as well as in 2006 and more recently (Fig. 8), related mainly to methods to study biodiversity and to the identified threats for biodiversity conservation.

Thus, in the 1990s, publications about persistent organic pollutants deserved great attention in the scientific community (Tilson et al. 1990; Murk et al. 1994; Safe 1994).

Later, the development of methods to study spatial distribution of wildlife at different scales, including models used to predict species presence, had a strong impact on wildlife research (Calenge 2006; Hirzel et al. 2006). Biodiversity is an ever-present topic in the challenge to harmonize food production and farming with the conservation of common and endangered species, and studies discussing strategies published in this period had also strong impact (Kleijn et al. 2006). At that time, the concept of ecosystem services as a means to value biodiversity gained relevance

(Losey and Vaughan 2006; Christie et al 2006; Power 2010). The increase and aggregation of human population is probably behind the rising interest for urban biodiversity in the last years (Chace and Walsh 2006; Goddard et al. 2010; Pickett et al. 2011). Finally, the concern about chemical pollutants highlighted in the 1990s has turned into an interest to identify the impact of emerging diseases on the conservation of biodiversity (i.e. bats or amphibians) (Frick et al. 2010; Kilpatrick et al. 2010; Altizer et al. 2011).

Ecology

The number of wildlife research publications within the topic of "ecology" is lower than the ones above, but has regularly increased throughout the study period. The marked peak in 1999 was due, as explained above, to the inclusion within this topic of the NCASI Technical Bulletin focusing on the relationships between forestry and wildlife.

Citation rate of papers within this topic did not show marked peaks throughout the study period, but maxima in 1996, 2002 and 2009–2011. The first one included highly cited methodological publications, including one for estimating animal home ranges (Kie et al. 1996) and the already mentioned one assessing how to quantify effects of human disturbance on animal populations (Gill et al. 1996). In 2002 appeared high impact publications on the ecology of emerging pathogens (Woolhouse 2002), but also a paper reviewing the economic reasons for conserving wild nature (Balmford et al. 2002), which further developed into the concept of ecosystem services. More recently, papers highlighted in this topic include ones about urban ecosystems (Chamberlain et al. 2009; Pickett et al. 2011); ecological effects of organohalogen contaminants (Letcher et al. 2010); and the already-mentioned ecological impacts of climate change in the arctic (Post et al. 2009).

Genetics

The field of genetics within wildlife research has only taken importance since 1998, according to the number of papers published in this topic (Fig. 8).

The increase in the occurrence of this topic followed the high impact of two publications in 1995 introducing the concept of population genetics and conservation genetics (Frankham 1995a, b). Subsequently, there has been a constant increase of this topic within wildlife research, and several peaks in citations have occurred. For instance, the concept of genetics became more present in highly cited publications about wildlife diseases (Hanlon et al. 1998; Tryland et al. 1998; Chua et al. 2002; Robinson et al. 2010). Several studies integrating the concept of population genetics in the conservation of species (Maudet et al. 2002; Bowen et al. 2005) and in strategies of extractives uses (Harris et al. 2002; Laikre et al. 2010) also had

strong impact. Moreover, using genetics to assess the potential of adaptation of wildlife to our changing world has also gained relevance (Nussey et al. 2005; Charmantier and Garant 2005). In recent years, the impact of landscape fragmentation on the genetics of the species has been addressed in some influential papers (Goddard et al. 2010; Shirk et al. 2010).

Extractive Use

The concept of wildlife has been historically linked to game animals, but the number of publications specifically mentioning hunting or extractive use is much lower than those on conservation or management (Fig. 8). Peaks in citation rates were not marked, but several issues and publications can be highlighted during the last 30 years.

Some early influential publications proposed the extractive use of some game species as a method to reduce overpopulation, with examples as geese species in North America (Ankney 1996). This contrasts with the publications based on other scenarios where the regulation of harvest is necessary to avoid the overharvest of some populations and the consequent spatial extinctions (McCullough 1996; Milner-Gulland and Bennet 2003; Corlett 2007). Another topic has been the study of the consequence of trophy hunting of genetic shifts and demography of the populations under pressure (Coltman et al. 2003; Milner et al. 2007; Allendorf et al. 2008; Packer et al. 2011). The behavioural response of game animals to human disturbance in relation to hunting has been another issue studied (Stankowich 2008), as well as the importance of game meat (bushmeat) in human nutrition of developing countries and its conflicts with conservation and sustainable use of such natural resource (Golden et al. 2011). Finally, the consequences of other extractive uses (i.e. fisheries or seal and whale hunting) on wildlife species have been the subject of some impact studies (Hall and Harding 1997; Trivelpiece et al. 2011). Moreover, the growing concern about climate change introduces new aspects in the decision making process for wildlife management, including extractive uses (Nichols et al. 2011).

Climate Change

This issue is of great interest for the general public currently, but the number of documents relating climate changes and wildlife just peaked very recently, after 2007 (Fig. 8).

Publications on this topic had already a strong scientific impact from 1995, with a study of the impact on wildlife of reforestation with the purpose of sequestering carbon (Englin and Callaway 1995). This highlights the interest of not only the impact of climate change on wildlife, but also of the measures adopted to cope with