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Geographic bias in citation rates of conservation research

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Abstract: *We investigated whether the impact of conservation science is greater for research conducted in countries with more pressing conservation problems. We quantified research impact for 231 countries based on 2 citation metrics (mean cites per paper and h index) and fitted models predicting research impact based on number of threatened bird and mammal species (as a measure of conservation importance of a country) and a range of demographic variables. Citation rates of conservation research increased as a country's conservation need increased and as human population, quality of governance, and wealth increased. Even after accounting for these factors, citation rates among regions and countries within regions varied significantly. The conservation research community needs to consider ways to begin addressing the entrenched disadvantages some countries have when it comes to initiating projects and producing high-quality research.*

Keywords: conservation biology, h index, research impact, threatened species

Sesgos Geográficos en las Tasas de Citas de la Investigación para la Conservación

Resumen: *Investigamos si el impacto de la ciencia de la conservación es mayor para las investigaciones llevadas a cabo en los países con problemas de conservación más apremiantes. Cuantificamos el impacto de la investigación en 231 países con base en dos medidas de citas (promedio de citas por artículo e índice h) y ajustamos modelos para predecir el impacto con base en el número de especies amenazadas de mamíferos y aves (como medida de la importancia de la conservación en un país) y en una gama de variables demográficas. Las tasas de citas de la investigación para la conservación incrementaron conforme incrementó la necesidad de conservación de un país y conforme incrementaron la población humana, la calidad del gobierno y la riqueza. Incluso después de considerar estos factores, las tasas de citas variaron significativamente entre las regiones y los países. La comunidad de la investigación para la conservación necesita considerar formas para comenzar a dirigirse a las desventajas arraigadas que algunos países tienen cuando se trata de iniciar proyectos y producir investigaciones de alta calidad.*

Palabras Clave: biología de la conservación, especies amenazadas, impacto de la investigación, índice h

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Introduction

In academic research, citation metrics are an important measure of research impact. Conservation research goals often include improved management practices, but citations of the research are still important because they indicate the impact of research within the research community (and perhaps broader societal impact) and high citation rates elevate the profile of researchers, institutions, journals, and research topics, which may be advantageous when making a case for funding conservation projects. To understand the impact of conservation science, it is important to understand the factors that influence citation rates and to identify systematic biases.

Citation rates vary with the publication medium, intended readership, research field, and publication language (Harzing & van der Wal 2008). Citation rates may also vary geographically, which should not be surprising, given the large differences among countries in research funding, opportunities, and output. In conservation science, one might also expect citation rates to vary geographically because the subject matter of conservation (biodiversity) is geographically heterogeneous. Hence, a null (or perhaps a naïve) expectation is that citation rates are high for studies conducted in countries where biodiversity is high or where conservation problems are pressing. However, there may be no association between conservation value of a country and citation rates of conservation research conducted in a country, or the association may be negative if research impact is lowest in developing tropical countries, where biodiversity tends to be high. If the association is negative, fewer citations could mean less scientific and public attention given to countries where conservation is most urgent.

We analyzed citation rates of conservation science research, focusing on associations between citation rates and conservation importance of a country and demographic and geographic factors across countries.

Methods

We quantified conservation importance of a country by recording its number of threatened mammal and bird species (IUCN 2014). We focused on mammals and birds because they have been the most completely assessed for the International Union for Conservation of Nature (IUCN) Red List, so there is likely to be less variation in sampling effort among countries relative to other taxonomic groups. This is a restrictive definition of *conservation importance* that is biased toward vertebrates and biodiversity known to be threatened. Thus, we included country area as a variable in our models because larger countries are likely to have high biodiversity generally (including landscape and ecosystem diversity as well as species numbers).

We used Publish or Perish software (Harzing 2007) to obtain country-specific citation rates of conservation research. This program uses Google Scholar to extract raw citations and generate citation metrics. The program provides flexible search definitions, and Google Scholar searches include books and book chapters, conference proceedings, working papers, and government reports, as well as journal articles. Google Scholar therefore captures much of the conservation research not published in the academic literature and hence much of the research used by conservation practitioners.

For each of 231 countries, we carried out separate literature searches (Supporting Information) of the full text (entire document, including title, author affiliations, main text, and references) and titles of publications. Search terms included country name in quotes plus *conservation* in quotes. For full-text searches, this returned many results not related to biodiversity conservation, so we excluded terms associated with molecular biology and terms that would return irrelevant results for particular countries (e.g., *equatorial*, *pig*, and *Bissau* for the country Guinea). All search and exclusion terms are listed in Supporting Information. Full-text searches resulted in automatic truncation of the search to the 1,000 most-cited papers for each country, so we limited the analysis to these 1,000. One of us scanned the results and removed obviously irrelevant publications. This filtered out most nonconservation publications. The result was a sample, rather than an exhaustive search, of the conservation literature, but the key consideration for our purposes was that search criteria were consistent across countries. Full-text searches unavoidably included authors' addresses, so they reflected countries in which researchers were based as well as countries that were the subject of the research. The title-only search did not have this problem, but it was less likely to return a complete list of publications relevant to each country. Thus, we used both kinds of searches to explore patterns in the citation data. From the search results for each country, we obtained 2 country-specific citation metrics: mean cites per paper and h index. Mean cites per paper was the sum of the citation counts across all papers for a country search divided by the total number of papers. The h index is the number of papers with a citation number $\geq h$ (Hirsch 2005) and is considered a good general indicator of research impact (Plume 2009). All citation searches were conducted between 20 December 2013 and 2 February 2014.

As a measure of conservation importance for each country, we used the number of mammal and bird species in each country listed as threatened (critically endangered, endangered, vulnerable, and lower risk-conservation dependent) on the 2008 IUCN Red List (the 2014 IUCN Red List was not available at the time of analysis). For comparison we also examined total numbers of mammal species per country.

For each country, we also recorded country area (www.nationsonline.org/oneworld/countries_by_area), per capita gross domestic product (GDP/capita) in 2012 (data.worldbank.org/indicator/NY.GDP.PCAP.CD), population (2012 revision of World Population Prospects), an unweighted average of 6 quality-of-governance indices (The World Bank 2012 Worldwide Governance Indicators), and geographic region (IUCN 2014).

To explore predictors of citation rates, we fitted linear models across countries with mean number of cites per paper and h index as response variables. For each response, we fitted a series of nested models, beginning with number of threatened species as the sole predictor, then successively adding area, GDP/capita, population, governance, and region. We transformed all continuous predictors to log values. We judged improvement in the model with the addition of each predictor by the change in the value of the Akaike information criterion (AIC). We then found a minimum adequate model (MAM) by deleting terms from a full model until all terms remaining were significant. We performed this set of tests separately with the outputs of both full-text and title-only literature searches. We then explored geographic variation in more detail by plotting (for each region) the residual geographic variation in citation rates that remained after accounting for all predictors other than region. We used full models (based on all continuous predictors) to calculate residuals, rather than MAMs, so that the distributions of residuals could be directly compared across models.

Results

There was substantial variation in citation rates among countries, whether quantified by citations per paper or h index or based on full-text or title-only searches (Supporting Information). The expectation that citation rates increase with a country's conservation importance was supported by significant positive associations between the number of threatened bird and mammal species and both measures of citation rate (Supporting Information). However, there remained a substantial amount of variation in citation rates not explained by number of threatened bird and mammal species (Supporting Information), and citation rates varied systematically by region (Supporting Information). These patterns were consistent with linear model results. Sequential addition of 5 of the predictor variables (threatened species, population, GDP/capita, governance, and region) to the model reduced AIC values for both full-text and title-only searches (Table 1). However, country area did not improve the fit of any of the models. The R^2 values of the MAMs showed that the predictor variables together explained 25-67% of the variance in citation rates (Table 1). However, not all the predictors that resulted in reduced AIC values appeared in the MAMs, probably reflecting intercorrelations or combined effects of some of the predictors.

Distributions of residual variation in citation rates that remained after accounting for continuous predictors were relatively similar across regions (Figs. 1 & 2), although the models showed that region still explained a significant part of the variance in citation rates. There were a number of outlier countries, with either unusually low or unusually high residual citation rates relative to other countries in their respective regions. Visualizing residual citation rates for individual countries on a global map (Supporting Information) further emphasized the geographic heterogeneity in citation rates and the existence of low- and high-performing countries in different regions.

Discussion

Our baseline expectation that citation rates are higher for countries with greater conservation importance was broadly supported. Conservation research with the highest impact within the research community tended to be conducted in countries with the most urgent conservation challenges, as expressed by the number of threatened bird and mammal species. But this measure of conservation importance explained only part of the variation in citation rates. Other significant (positive) effects on citation rates were population, wealth (GDP/capita), and quality of governance. These results are not surprising. Countries with larger populations tend to have more research institutions and more scientists and to produce a greater volume of research (http://www.scimagojr.com/countryrank.php). There is a direct link between research volume and h index (which can only increase as the number of publications increases), but this link was not necessarily expected for citations per paper. Nonetheless, population still figured as a significant explanatory variable in most of the models for citations per paper. The explanation for this may be that countries producing a large quantity of research also produce research that varies broadly in quality, which should elevate the mean number of citations per paper as well as the h index. High GDP and governance quality may be associated with high research impact indicators for a variety of reasons. Such countries typically spend more money on science, have better scientific infrastructure and expertise, and a more deeply embedded scientific culture and tradition (The Royal Society 2011). The fact that governance quality, but not GDP, appeared in the minimum adequate models suggests that governance quality reflected science investment and infrastructure well.

The demonstrated geographic bias in citation rates in the conservation literature reflects findings by Lawler et al. (2006). Their study of the global conservation

Table 1. Comparisons of values of Akaike information criterion (AIC) for linear models predicting citation rates (mean cites per paper and h index) of conservation research among countries from predictors describing the conservation importance (number of endangered species), population, geographic area, wealth (gross domestic product [GDP]), and geographic region of countries.*

Response	Model	AIC full-text searches	AIC title-only searches
Cites per paper	endangered species	1607.4	881.4
	endangered species + population	1586.3	868.6
	endangered species + population + GDP	1549.0	869.2
	endangered species + population + GDP + governance	1483.2	847.3
	endangered species + population + GDP + governance + area	1485.2	846.7
	endangered species + population + GDP + governance + area + region	1424.6	832.1
	minimum adequate model (full-text searches): population + governance + region	1422.8	
	minimum adequate model (title-only searches): endangered species + governance + region		829.6
h index	endangered species	1736.2	1321.7
	endangered species + population	1713.3	1291.3
	endangered species + population + GDP	1680.9	1270.1
	endangered species + population + GDP + governance	1606.3	1204.3
	endangered species + population + GDP + governance + area	1608.2	1206.3
	endangered species + population + GDP + governance + area + region	1524.2	1186.1
	minimum adequate model (full-text searches): population + governance + region	1520.6	
	minimum adequate model (title-only searches): endangered species + population + governance + region		1185.0

**All continuous variables are log transformed. Results are shown for literature searches of the full text and title only of publications. The R^2 values for the minimum adequate models (MAMs) are as follows: cites per paper, full-text searches (FT), $R^2 = 0.62$; cites per paper, title-only searches (TO), $R^2 = 0.25$; h index, FT, $R^2 = 0.67$; and h index, TO, $R^2 = 0.64$.*

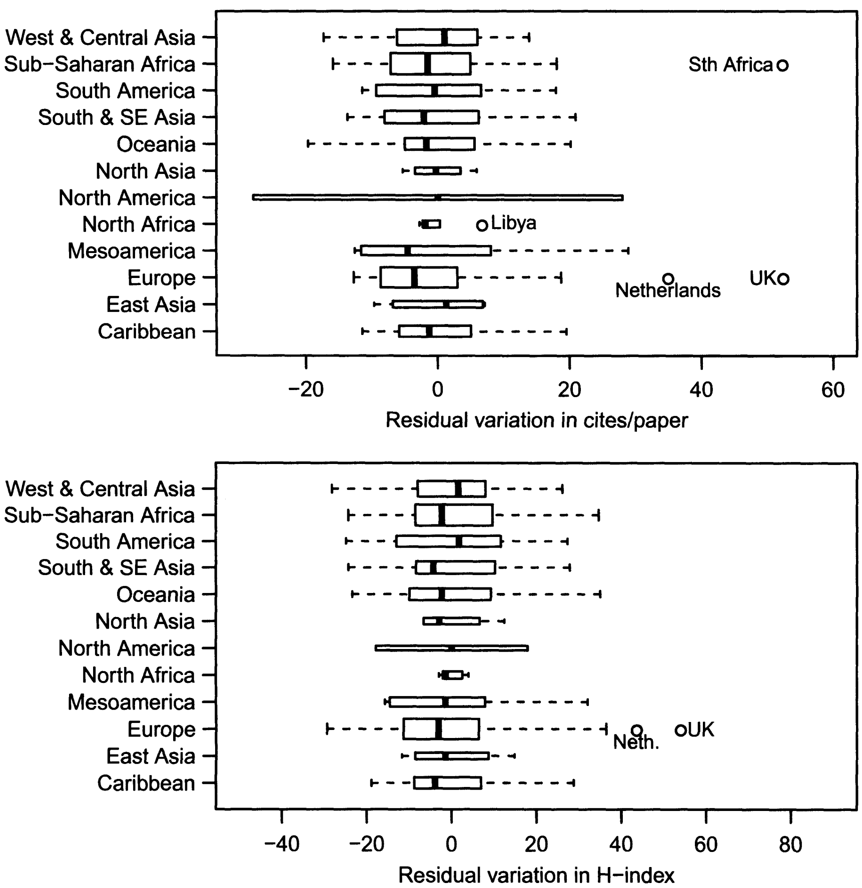

Figure 1. Residual variation in citation rates of conservation research from full-text literature searches by region. Research impact is quantified based on (a) citations per paper and (b) h index (bars, distributions of residuals from models predicting research impact based on the number of threatened bird and mammal species, population, governance, and per capita gross domestic product across countries; vertical lines, median value; horizontal box length, 95% of values; dashed lines, 99% of values; points, outliers; vertical box width, proportional to sample sizes [i.e., number of countries in the region]).

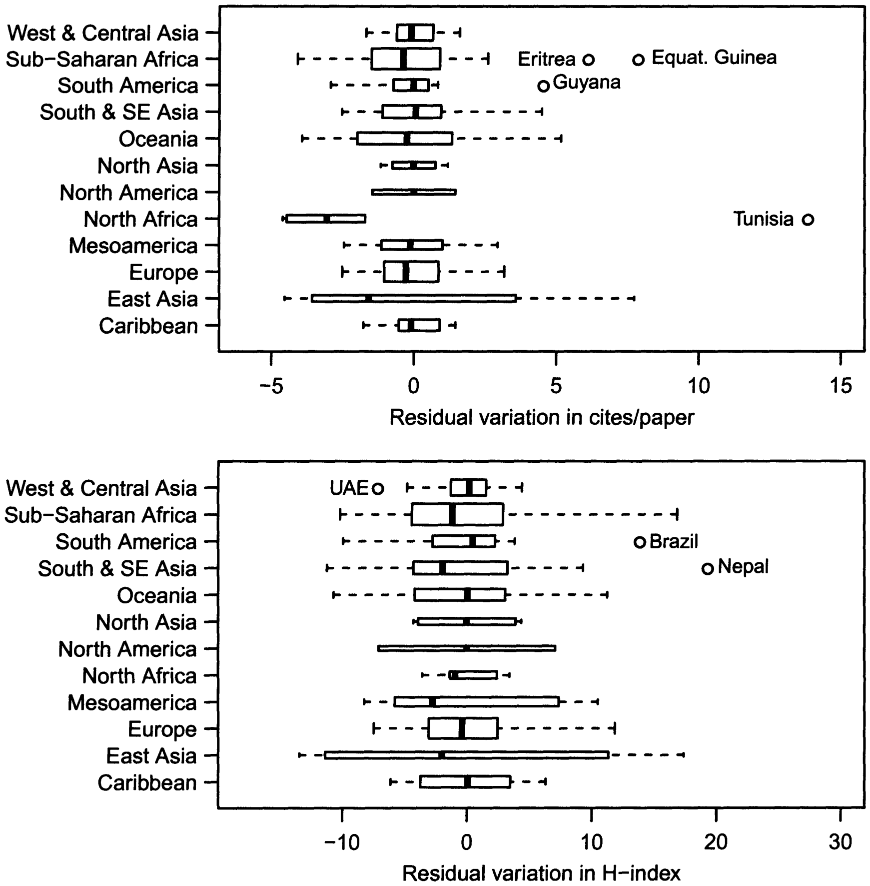

Figure 2. Residual variation in citation rates of conservation research from title-only literature searches by region. Research impact is quantified based on (a) citations per paper and (b) h index (bars, distributions of residuals from models predicting research impact based on the number of threatened bird and mammal species, population, governance, and per capita gross domestic product across countries; vertical lines, median value; horizontal box length, 95% of values; dashed lines, 99% of values; points, outliers; vertical box width, proportional to sample sizes [i.e., number of countries in the region]).

literature indicated eco-geographic gaps in conservation research; some biomes were less studied than others. They found that research intensity outweighed conservation priorities in the United States, United Kingdom, and much of Europe, whereas research efforts lagged behind conservation priorities in much of Asia, South America, and the Indo-Pacific. The major differences between our study and that of Lawler et al. (2006) are that their focus was on the quantity of conservation research, whereas our focus was on research impact, and that their units of analysis were ecologically defined biomes, whereas ours were countries. We believe it is important to analyze patterns across countries because it is at the level of national government that most conservation decisions are made. To the extent that countries in the same regions share similar political and scientific traditions, the across-country patterns we found may help explain the patterns across biomes discovered by Lawler et al. (2006).

Even when conservation importance, population, wealth, and governance were accounted for, there remained significant geographic variation in conservation research impact. This suggests that there may be other variables that better describe conservation importance than the number of threatened bird and mammal species. When we repeated our models using total numbers of mammal species per country, the results were very similar to those we obtained using the number of threatened bird and mammal species (Supporting Information; data on total numbers of bird species per country were not easily obtainable). To some extent, therefore, the number of threatened species can be considered a reflection of total biodiversity, rather than an independent measure of the urgency of conservation needs, although we do not think this is necessarily an important distinction to make.

Variables describing a country's scientific infrastructure, funding, or opportunities may capture some variation in citation rates. The high-performing outlier countries seem to bear this out. These are countries that produce research of higher impact than other countries in their region after conservation importance, population, wealth, and governance are accounted for. These high performers include some high-biodiversity countries for which conservation value is not necessarily best described by the number of threatened species that are also comparatively politically stable and accessible to international researchers, or that have a strong domestic research program (Brazil, Equatorial Guinea, Guyana, South Africa). The high performers include the Netherlands and the United Kingdom, countries with low biodiversity but strong scientific traditions and well-funded institutions. The presence of these countries as outliers for full-text, but not title-only, searches (Figs. 1 & 2) probably reflects the fact that the full-text searches picked up authors' institutions as well as countries where the research took place (although doubtless much research is done in authors' home countries). Other positive outliers were more surprising, including Libya, Eritrea, and Tunisia, although Tunisia is identified by the Royal Society (2011) as an "emerging scientific nation" with rapid growth in scientific output since 1996. In contrast, another emerging scientific nation, the United Arab Emirates, was a negative outlier within in west and central Asia, perhaps because its very recent increase in science investment has yet to translate into improved citation rates.

We have explained geographic variation in research impact in terms of external factors, but to what extent is this geographic variation self-perpetuating? That is, will the poor citation record of research from a country influence the likelihood of international researchers initiating projects there or of local researchers working in their home countries rather than seeking opportunities abroad? Most researchers probably do not explicitly take citation rates into account in deciding where to work and are probably not even consciously aware that, for example, conservation-focused papers about Thailand are cited 5 times less often, on average, than papers about conservation in the United States. But the poor impact of research from a country may be part of a vicious circle. The success of funding applications for projects depends partly on the momentum generated by a long tradition of scientific work, well-established scientific expertise and infrastructure, and a record of high-profile research outputs. Conservation scientists in countries that lack this momentum and have a low-profile research record will likely be required to extend substantial extra effort to secure funding, get new projects started, and gain international scientific recognition. The time lags before elevated research output translates into citations can be considerable (The Royal Society 2011).

The increasing use of citation metrics to assess research impact and academic success means that increasingly conservation scientists are aiming to publish their work in respected, high-ranking journals (e.g., Bornmann & Daniel 2005; Belmaker et al. 2010). This highlights the issue of whether high research impact translates into important outcomes for practical conservation (e.g., Cardillo & Meijaard 2012; Meijaard et al. 2014). It could be argued that high-impact research does not aim to influence day-to-day management; rather, it aims to influence policy and planning aspects of conservation (S. Stuart, personal communication). Assuming high research impact has at least some conservation influence, the research community should consider ways to address the entrenched disadvantages some countries face. These could include promoting conservation research programs aimed specifically at countries that are biologically worthy but lag behind in their scientific track record or fostering collaboration between researchers in such countries and countries with a strong international research presence. Perhaps the ultimate aim of such programs should be research impact that more closely reflects conservation need and biological interest, rather than size, wealth, quality of governance, or history.

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Supporting Information

The complete data set of country-specific citations, geographic and demographic data (Appendix S1), plots of number of threatened birds and mammals relative to citation rates for full-text searches (Appendix S2), plots of number of threatened birds and mammals relative to citation rates for title-only searches (Appendix S3), maps of model residuals for full-text searches (Appendix S4), and maps of model residuals for title-only searches (Appendix S5) and linear model results for total mammal species (Appendix S6), are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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