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# What determines the citation frequency of ecological papers?

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**Citation frequencies of scientific articles are increasingly used for academic evaluation in various disciplines, including ecology. However, the factors affecting citation rates have not been extensively studied. Here, we examine the association between the citation frequency of ecological articles and various characteristics of journals, articles and authors. Our analysis shows that the annual citation rates of ecological papers are affected by the direction of the study outcome with respect to the hypothesis tested (supportive versus unsupportive evidence), by article length, by the number of authors, and by their country and university of affiliation. These results cast doubt on the validity of using citation counts as an objective and unbiased tool for academic evaluation in ecology.**

How do papers get cited, and why are some cited more than others? Citations are traditionally regarded as the formal acknowledgement of the previously published sources of information that relate to the citing author's research [1]. Thus, the number of times that a publication has been cited by other authors might indicate its overall scientific utility [2]. Given that utility is one aspect of scientific quality, citation counts are commonly used by decision makers to assess the academic performance of individual researchers, departments and research institutions when making decisions about funding, hiring, promotion and tenure [3,4], as well as to compare the development of different disciplines [5] and national scientific outputs [6,7]. The use of citation counts for academic evaluation has increased rapidly since the introduction of computerized citation indexes [4], and citation scores have been advertised as objective quantitative indicators of scientific performance and a valuable addition to conventional methods of research evaluation, such as peer review [3].

The use of citation counts for academic evaluation is based on the assumption that authors select references based on their relevance and contribution to the author's own work, and that all important sources are credited by citation. However, in practice, the abundance of available literature and journal space limitations prevent authors from citing all the used sources, resulting in only a small proportion of the literature base of a scientific paper being cited [8]. This selection pressure might lead to potential bias in the choice of citations, and leaves room for several secondary motives that might affect citation decisions [9,10], such as persuasiveness (convincing the reader about the correctness of the methods and results) [11], flattery (citations of editors and influential colleagues who are likely to be used as referees) [12] or interpersonal connections to cited authors (preferential citing of colleagues within an institution) [13]. In addition, cases of selective citing of studies providing supportive evidence [14–16] as well as those of nationality [17–18] and gender [19–20] bias in citation selection have been reported in some fields. Therefore, although providing an illusion of objectivity, citation counts might be affected by a variety of subjective and social factors. As a result, the validity of using citation analysis for research evaluation has been repeatedly questioned (e.g. [4,12,17,18,21,22]).

To what extent are these concerns about the objectivity of citation counts justified in ecology? Although several papers have addressed the issue of nationality and gender bias in citations of ecological papers [17,23,24], the relative importance of other factors associated with citation rates of ecological papers has not been quantitatively studied in detail. Here, we examine systematically the association between the citation frequency of ecological articles and various characteristics of journals, articles and authors, using four independent data sets (Box 1). We reason that, if citations reflect the scientific utility of a study, citation rates should be associated primarily with the characteristics of that study *per se*. However, if social factors play a significant role in reference selection, we might expect citation rates to correlate with author characteristics, journal prestige and/or the direction of study outcome with respect to the hypothesis tested.

## Citation rates and journal impact factors

The papers used in our analysis were published in 53 ecological journals with different impact factors (Box 1) and so we examined the relationship between the citation rates of individual papers and the impact factor of the journals in which they were published. The journal impact factor describes the mean citation rate of articles published in a given journal [25] and is calculated by dividing the number of citations received in the current year (e.g. 2003) for articles published in the journal in the previous two years (i.e. 2002 and 2001) by the total number of articles published in the journal in those previous two years (ISI Journal Citation Reports ®; http://isi10.isiknowledge.com/portal.cgi/wos).

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**Box 1. The data sets**

The first data set used in our evaluation [42] comprises studies testing the plant stress (PS) hypothesis, which predicts that abiotically stressed plants are more susceptible to herbivorous insects than are those that are not stressed [43]. This hypothesis has been tested experimentally by subjecting woody plants to various types of stress (drought, pollution, etc.) and assessing insect herbivore performance or density on control and experimental plants. Increased insect performance on stressed plants is interpreted as evidence supporting the PS hypothesis.

The second data set [44] consists of studies testing the carbon–nutrient balance (CNB) hypothesis [45] by examining changes in concentrations of carbon-based secondary compounds in woody plants in response to nitrogen fertilization. The CNB hypothesis predicts that the production of carbon-based secondary compounds is decreased by factors that reduce photosynthesis more than they do growth or stimulate growth more than they do photosynthesis. Reduction in concentrations of carbon-based secondary compounds in response to fertilization is interpreted as evidence supporting the CNB hypothesis.

The third data set [46] comprises studies testing the prediction that plant antiherbivore defences are costly in terms of fitness because allocation to defence diverts the resources away from growth and reproduction [47]. Costs of defence are measured by estimating phenotypic correlations between plant defence and fitness traits, and significant negative correlations are taken as evidence of costs.

The fourth data set [34] consists of published and unpublished articles from Finnish and Swedish doctoral dissertations covering various ecological topics; they were used to test the hypothesis that statistical significance of results affects the publication fate of ecological studies.

**Methodology**

From the first three data sets, we selected only those studies that aimed specifically at testing one of the three hypotheses (PS, CNB and the cost of defence hypotheses). From the fourth data set, we selected only the published papers for which citation counts were available. The number of citations received by individual papers as of January 2004 was obtained from the Science Citation Index® (http://isi10.isiknowledge.com/portal.cgi/wos). To correct for differences in publication year, an annual citation rate was calculated for each paper by dividing the total citation count by the number of years since publication. The total database consisted of 228 primary research articles published from 1975 to 2001 in 53 different ecological journals with impact factors ranging from 0.39 to 4.73. The annual citation rates of individual ecological papers correlated positively with journal impact factor ($r=0.62$, $P=0.0004$, $N=216$), although there was lot of variation in citation rates of papers published in journals with the same impact factors (Figure I). Because the correlation was statistically significant, we standardized citation rates by the journal impact factor in all our subsequent analyses by means of partial correlation and analysis of covariance.

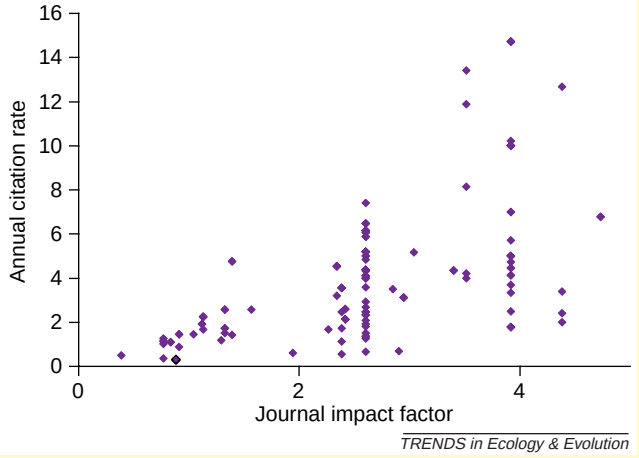


**Figure I.**

Annual citation rates of individual ecological papers correlated positively with journal impact factor (Box 1). Similarly, others have found that the impact factor of the original publishing journal is the strongest predictor of annual citation rates of studies in emergency medicine [26], while a weaker correlation was found between the 'citedness' of individual biomedical articles and their corresponding journal impact factors [27]. A positive relationship between citation rates of individual articles and journal impact factors might reflect the fact that citation rates of individual papers contribute to the journal impact factor. However, this relationship could be interpreted as an indication that publication in a high-impact journal might by itself enhance the citation rate of an article by increasing its visibility or persuasiveness of the arguments presented [28]. This seems to be a widespread belief, which makes scientists increasingly desperate to publish in the few 'top' journals [29]. Our results, however, do not support this 'journal effect' hypothesis, because there was considerable variation in citation rates, especially for papers published in high-impact journals (Box 1). This indicates that publication in a high-impact journal does not by itself guarantee high citation rates.

The correlation between annual citation rates of individual papers and the impact factor of the journals would be lower if our data sets included papers published in multidisciplinary journals, such as *Science* and *Nature*, because citation rates of ecological papers published in such journals are lower than those of papers from other biological disciplines [5]. Therefore, we conclude that journal impact factors are not representative of citation rates of individual ecological articles.

## Citation rates and individual study characteristics

We examined the association between citation rates and two types of study characteristic: study outcome and article length. Several studies in medicine and psychology have found that the outcome of studies with respect to the hypothesis being tested influence citation rates, with either supportive or unsupportive results receiving more citations depending on the research area [14–16,26,30,31]. We found that the direction of study outcome with respect to the hypothesis tested might also influence the citation rate of ecological papers, but the direction of the effect depends on the particular hypothesis being tested (Box 2). Studies supporting a widely accepted hypothesis might receive more citations than would studies that reject it. However, if a hypothesis has received criticism or is countered by an alternative hypothesis, studies with unsupportive results might receive more citations than would those supporting the hypothesis. All three hypotheses tested here have received criticism and have not been widely accepted without doubt and discredit. However, the plant stress hypothesis is the only one with an alternative

**Box 2. Citation rates in relation to study outcome**

Most papers examined tested a specific ecological hypothesis. The results of studies either supported the hypothesis tested, rejected it, or were statistically non-significant. The statistical significance of the results, in turn, depends on the magnitude of the effect and the sample size. Therefore, to determine whether citation rates of ecological papers are affected by study outcome, we examined the relationship between citation rates and direction and magnitude of the reported effect, as well as the sample size.

**The magnitude and direction of research findings**

To test for the effects of the direction and magnitude of an effect size on citation rates, we calculated correlations between citation rates and the reported effect sizes for data sets 1–3 (Box 1). Significant correlations were found in two out of three tested data sets. The greater the reported increase in performance of insect herbivores on stressed plants (and, thus, the stronger the support for the plant stress hypothesis), the fewer citations those studies attracted ($r=-0.467$, $P=0.029$, $N=23$). By contrast, the stronger the reported negative correlations between plant defence and the fitness measures (and, thus, the stronger the evidence of defence costs), the more citations those studies received ($r=-0.386$, $P=0.035$, $N=31$). No relationship was found between citation rates and the outcome of studies testing the carbon–nutrient balance hypothesis ($r=0.240$, $P=0.212$, $N=29$). To test whether it was the direction or the magnitude of the reported effect that affected the citation rates, we recalculated correlations using the absolute magnitude of the effect size. No relationship was found between citation rates and the absolute magnitude of the effect size in any of the three data sets ($r=0.190$, $P=0.398$, $N=23$; $r=0.061$, $P=0.647$, $N=59$; $r=0.246$, $P=0.189$, $N=31$, respectively).

**Statistical significance of the research findings**

The fourth data set was used to test whether statistical significance of results affected annual citation rates. No significant relationship was found between annual citation rates and the proportion of non-significant results in a study ($r=0.0081$, $P=0.928$, $N=127$).

**Sample size**

No significant relationship was found between sample size and citation rates in data sets 1–3 ($r=-0.137$, $P=0.542$, $N=23$; $r=-0.142$, $P=0.287$, $N=59$; $r=0.196$, $P=0.299$, $N=31$, respectively).

exclusive hypothesis, namely the plant vigour hypothesis [32]. Thus, authors might have cited papers that do not support the plant stress hypothesis to support the plant vigour hypothesis instead. Therefore, our results support the view that citations are commonly used as tools of persuasion rather than as a way to acknowledge the information source [11].

Interestingly, unlike the direction of the research findings, neither their absolute magnitude (absolute effect size) nor their statistical significance influenced citation rates (Box 2). It has been previously shown that the absolute magnitude and statistical significance of the reported effect size affect the place of publication of ecological studies, with stronger and statistically significant results being published in journals with a higher impact factor [33,34]. Our results indicate that the final step of the publication process (citation by subsequent authors) appears to be free of this bias. Furthermore, unlike in medicine [26,35], the citation rates of ecological papers were not related to study sample size, which determines the power of statistical tests and, thus, can be considered as one of the indictors of the methodological quality of a study.

In addition to the direction of study outcome with respect to the hypothesis tested, the length of an ecological paper appears to affect its citation rates. Longer papers receive more citations than do shorter ones, as indicated by a significant positive correlation between the length of a paper in pages and its annual citation rate ($r=0.136$, $P=0.0472$, $N=216$: partial correlation corrected for journal impact factor). One might expect this result given that longer papers have higher visibility in a journal and have more content that can be cited. In addition, the length of an article might also imply a quality element because, given the high competition for journal space, a longer article will be accepted only if its length is judged by the peer reviewers and editors to be appropriate relative to its information content.

## Citation rates and authorship characteristics

A recent survey [36] revealed that, of the authors publishing in five leading ecological journals, only 6% were females, which suggests a gender bias among senior ecologists. The range of ecological journals examined in our survey was much broader (53 versus 5) and, as a result, the proportion of articles written by females was much higher (30%). We found that gender of the first author had no effect on the citation rates of individual ecological papers (Box 3). This is in agreement with the results of a previous analysis, which showed a lack of gender bias in the refereeing and citation process in ecology [23]. Thus, the citation process in ecology is potentially less sexist compared with some other disciplines [19,20].

In contrast to author gender, the number of authors and the first author's affiliated country and university significantly affected the citation rates of ecological papers (Box 3). Papers with four or more authors received more citations than did papers with fewer authors. Our result complements the recent finding that ecological papers with four or more authors have a higher chance of being accepted for publication [23], although, this study found that such papers were cited less than were papers with fewer authors. The higher citation rates received by multi-authored papers might reflect the multidisciplinarity of such articles [37] or the benefits of division of labour. In addition, the higher the number of authors, the larger the network of scientists that might know of one of them and, thus, cite them. Alternatively, the increase in citation rates with the number of authors might be related to an increased frequency of self-citations in the case of multi-authored papers [38].

We found that papers written by authors from countries where English is a national language attract significantly more citations than do papers written by authors from non-native English speaking countries (Box 3). A similar pattern has been observed for both citation rates and probability of acceptance of ecological papers [23]. In addition, we found that papers written by US authors received more citations than did papers by European authors. These patterns could be due either to the higher quality of publications produced by ecologists from US and other English-speaking countries or to the parochial citation practices exhibited by these researchers [12,17,24]. In addition, the total number of citations received by papers

**Box 3. Which authorship characteristics influence citation rates?**

All four data sets were used to examine the relationship between annual citation rates and various author characteristics that have been previously suggested to affect citation rates [23,48].

### Author gender

No effect of the gender of the first author on annual citation rates was found ($F=0.19$, $df=1$, $P=0.667$, $N=187$). Studies where gender was not apparent from the author's first name or only the initials were given were excluded from the analysis.

### Number of authors

To examine the influence of number of authors on citation rates, author number was divided into four groups (one, two, three, and four or more authors). Papers with four or more authors received more citations than did papers with one, two or three authors ($F=3.03$, $df=3$, $P=0.031$, $N=214$) (Figure I).

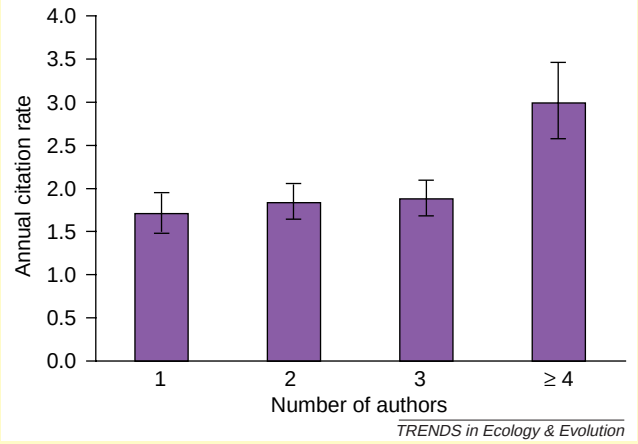


**Figure I.** Effects of the number of authors on annual citation rates of individual papers. Back-transformed covariate (journal impact factor) adjusted least square means and standard errors are presented here.

### Alphabetical position of author's surname

We failed to replicate the finding of Tregenza [48] that authors whose surnames begin with letters closer to the beginning of the alphabet receive more citations than do those authors with surnames closer to the end of the alphabet. No significant relationship was found between the alphabetical position of the first author's surname and citation rates ($r=-0.092$, $P=0.175$, $N=219$).

### Country of affiliation

We tested whether citation rates of ecological papers differ depending on whether the first author is from an English-speaking country. The citation rates of US authors were also compared with those of European authors. We found that papers by authors from non-English-speaking countries attract significantly fewer citations than do papers by native English-speaking authors ($F=6.85$, $df=1$, $P=0.009$, $N=216$) and that papers by US authors receive more citations than do papers by European authors ($F=6.74$, $df=1$, $P=0.010$, $N=210$).

### Affiliated university

For US authors, we tested the relationship between the citation rates of individual articles and the ranking of the university with which the first author was affiliated at the time of publication. We used the Academic Ranking of World Universities 2003, conducted by the Institute of Higher Education Shanghai Jiao Tong University (http://www.the-funneled-web.com/rank-1-100.htm). We found a marginally significant negative correlation between citation rates and the ranking of the US universities ($r=-0.242$, $P=0.060$, $N=61$), indicating that scientists from top-ranking universities tend to receive more citations than do authors from lower-ranking universities. We were unable to conduct the analysis for European authors owing to an insufficient sample size.

written by European authors from non-native English speaking countries is probably underestimated in our analysis because such papers are also likely to receive citations in national-language literature, and publications in languages other than English have only limited coverage in the Science Citation Index [39].

Papers produced by researchers from the top US universities tended to receive more citations than those from US universities positioned lower in the ranking list (Box 3). Again, it is not clear whether this pattern is due to higher quality science produced by researchers in top-ranking universities or to institutional prestige and the belief that references to work conducted at top-ranking universities would make arguments more compelling for the readers.

## Conclusions

Our report is, to our knowledge, the first attempt to examine systematically the importance of various factors associated with the citation rates of ecological studies. The correlative nature of our study and the complex nature of the explanatory characteristics used make it difficult to interpret unambiguously the ultimate causes behind the observed associations. Nevertheless, the patterns that we detected suggest that factors other than the scientific utility of a study affect citation rates in ecology. We found that, although citation rates of ecological papers are associated with only a few study characteristics, they are associated with most of the author characteristics that we examined. This suggests that social factors, such as the professional standing of the cited author, play a significant role in citation decisions in ecology. Furthermore, the dependence of the citation rates of ecological papers on the direction of study outcome with respect to the hypothesis tested suggests that citations in ecological papers are used as rhetorical devices to convince the readers of the validity of the study claims rather than as simple acknowledgements of the sources of background information. Persuasive style is important in scientific writing and there is nothing wrong in choosing references to support the claims made. What is wrong is to knowingly ignore citing disconfirming evidence or a relevant paper, which is written by a less well known researcher. It is our concern that, similarly to the process of publication [29], the process of citation in ecology becomes a political issue and sometimes receives priority over the science itself.

In spite of the identified shortcomings, the practice of academic evaluation using bibliometric indicators such as citation counts is unlikely to be abandoned in the near future; such indicators are easily accessible and represent the best indicators of scientific utility currently available. To that end, the results of our study could help ecologists to develop publication strategies that would increase their chances in the 'citation game' without compromising the

quality of the science produced. For instance, our results indicate that the strategy of slicing the results of a study into the 'minimal publishable units' does not necessarily pay off; although increasing the number of publications, it significantly decreases the number of citations per publication. Similarly, the broad scatter of citation rates of individual articles in ecological journals with a high impact factor indicates that publication in a prestigious journal does not by itself guarantee high citation rates. Instead, collaborative work involving several researchers might result in a citation bonus compared with studies performed by a single researcher ([40], but see [38,41]). We hope that our study will stimulate more detailed analyses of individual factors associated with citation frequency of ecological studies.

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