Does Scientific Collaboration Increase the Impact of Ecological Articles?

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We examined the effects of different types of collaboration on the citation rates of 837 research papers published in Oecologia from 1998 through 2000. Multiauthored papers had higher annual citation rates, but also higher self-citation rates, than single-authored papers. Interdisciplinary collaboration between institutions increased citation rates, whereas in-house collaboration reduced them. Contrary to our predictions, international collaboration had no effect on the citation rates of ecological papers, and US ecologists benefited from collaboration more than their European colleagues. Altogether, our results indicate that scientific collaboration in ecology has a rather minor effect on the impact of the resulting publications, as measured by their citation rates.

Keywords: citation rates, coauthorship, domestic collaboration, international collaboration, multidisciplinarity

Scientific collaboration, especially international and interdisciplinary collaboration, has expanded rapidly in all fields of research (Avkiran 1997, Glänzel 2001) and has become a topic of increasing interest for both scientists and science policymakers (Moed et al. 1991, Katz and Hicks 1997). Collaboration can be beneficial for several reasons: it provides a larger pool of available ideas, methods, and resources, and it allows cost sharing and time saving as a result of division of labor (Avkiran 1997, Katz and Martin 1997). Consequently, scientific collaboration is commonly considered a prerequisite of high-quality research, and numerous initiatives by the European Commission and national governments have been launched with the aim of promoting collaboration among researchers (Katz and Martin 1997). The degree of collaboration is also often taken into account when making funding, hiring, and promotion decisions (Katz and Martin 1997).

Although scientific collaboration is widely assumed to enhance the quality and impact of scientific research, the evidence for this assumption is contradictory. Using coauthorship as an indicator of collaboration, several studies have examined the impact of scientific collaboration by comparing the citation rates of single- and multiauthored articles. Citation frequencies are assumed to indicate the scientific utility of a study and thus can be used as a partial indicator of study quality and impact (Lawani 1986). The number of authors has been shown to increase the citation rates of individual articles in some disciplines (Abt 1984, Smart and Bayer 1986, Katz and Hicks 1997, Glänzel 2002, Aksnes 2003), although in other fields no such relationship has been observed (Smart and Bayer 1986, Avkiran 1997, Rousseau 2001). A critical question when interpreting the positive relationship between the number of authors and citation rates is whether this pattern reflects a true benefit of collaboration or is due simply to the increased proportion of self-citations in multiauthored papers (Herbertz 1995) or to the increased probability that such papers will be brought to the attention of the citer through personal contacts with at least one of the authors (Goldfinch et al. 2003). Furthermore, coauthorship is only a partial indicator of collaboration; it provides no insight into the precise nature and magnitude of collaboration (Katz and Martin 1997).

The potential benefits of scientific collaboration may depend on the type of collaboration, the discipline, and the country or countries involved. For example, international collaboration is generally considered to increase citation rates more than domestic collaboration (Narin et al. 1991, Katz and Hicks 1997, Goldfinch et al. 2003) and to be especially beneficial for scientists from small universities and small or
The impact of scientific collaboration on the quality and visibility of the resulting publications has not been explicitly studied in ecology, although two recent studies have demonstrated that the number of authors affects the probability of acceptance and the citation rates of ecological papers (Tregenza 2002, Leimu and Koricheva 2005). In the present study we examine the effects of different types and levels of collaboration on the citation rates of individual research articles to find out whether some collaboration strategies lead to a greater impact than others. We address the following questions:

- Do the citation rates of ecological papers increase with the number of authors?
- If so, is this trend due to an increased share of self-citations in multi-authored papers?
- Do different types of collaboration (international, domestic, and in-house) affect citation rates differently?
- Does interdisciplinary collaboration increase citation rates?
- Are there differences in patterns and benefits of collaboration between US and European ecologists?

**Literature survey**

We examined all articles published in the journal *Oecologia* from 1998 through 2000. *Oecologia* was chosen for the survey because it is a well-established ecological journal with no bias as to research topics or plant and animal taxa studied. In addition, *Oecologia* has both European and American editorial boards, and has a comparable number of authors from both North America and Europe. We therefore considered papers published in *Oecologia* to be more or less representative of ecological research in general. Furthermore, restricting the scope of the survey to a single journal eliminates the journal impact factor as a possible confounding variable in the analysis. The time span 1998-2000 was chosen because we were particularly interested in examining the recent patterns and trends in the influence of collaboration on scientific impact. The number of citations did not differ markedly between the years and ranged from no citations to tens of citations per paper. Reviews, methodological articles, and invited contributions for special issues were excluded from the analysis. The final data set consisted of 837 research articles.

For each article, we recorded the number of authors, the first author's country of affiliation, the number of countries and institutions of affiliation, and the number of biological fields represented by the authors, as indicated by the names of the departments of affiliation. The last-mentioned variable was used as an indicator of the interdisciplinarity of collaboration. The total number of citations received by individual articles as of July 2004 was obtained from the Science Citation Index, or SCI, of the Thomson ISI (Institute for Scientific Information). The number of self-citations was calculated by examining the list of authors of each citing article. All citations for which at least one of the authors of the cited paper was involved as a coauthor in the citing paper were considered as self-citations. Annual citation rates and annual self-citation rates were calculated by dividing the number of citations and self-citations by the number of years since publication.

**Statistical analyses**

We first examined the relationship between the annual citation rates of individual articles, both including and excluding self-citations, and the number of authors, using Pearson's correlation analysis. To examine the effects of different types and levels of collaboration on scientific impact, we conducted analyses of covariance to test the effects of the number of institutions (one, two, or more), the number of countries (one, two, or more), and the number of biological fields (one or more) on the annual citation rates. The number of authors was used as a covariate. Annual citation rates were log-transformed to meet the assumptions of normal distribution and the homoscedasticity of the variances. The assumption of homogeneous regression coefficients across the categorical variables was tested by including all possible interactions between the covariate and the categorical variables in the model. None of the interactions was statistically significant, as required to meet the assumptions of ANCOVA (analysis of covariance). The results of the analysis were the same regardless of whether self-citations were excluded or included. We therefore present only the results of analyses with self-citations excluded.

To examine the effect of the type of collaboration on scientific impact, we classified collaboration as (a) domestic in-house collaboration (all authors from the same institution), (b) domestic multi-institutional collaboration (all authors from the same country but from more than one institution), and (c) international collaboration (authors from more than one country), and tested whether annual citation rates differed among these different levels of collaboration by conducting an analysis of variance. Annual citation rates were log-transformed to meet the assumptions of ANOVA (analysis of variance), and self-citations were excluded.
We further tested whether annual citation rates and self-citation rates differed between American and European authors by conducting one-way ANOVAs. To test whether the influence of collaboration on scientific impact varied between American and European authors, we conducted separate ANCOVAs for American and European authors and tested the effects of the number of countries, the number of institutions, and the number of biological fields on annual citation rates using the number of authors as a covariate. Citation rates were log-transformed to meet the assumptions (of normal distribution and of the homoscedasticity of the variances), and self-citations were excluded.

To test for possible national differences in citation patterns (Møller 1990, Wardle 1995), we selected from our data set 15 papers by US ecologists and 15 by European ecologists. These papers were randomly selected from those whose authors all came from the same country. For the European papers, the sample included papers authored by researchers from nine different countries; the countries included, and the number of papers per country, were chosen to reflect the relative frequency of papers by researchers from these countries published in *Oecologia*. For the articles selected, we checked all papers that were cited in them and selected those that were available in the ISI database. We counted the proportion of US and European papers cited in each of the papers and tested the difference between these proportions separately for American and European ecologists, using Kruskal-Wallis nonparametric tests. The percentage of citations to American or European authors of the total ISI citations per paper was used in the analysis.

**Results of the survey**

We found that 85 percent of the papers published in *Oecologia* from 1998 through 2000 were multiauthored (82 percent of US papers and 86 percent of European papers); authors from more than one institution were involved in 41 percent of the papers, and 19 percent of the papers were written by authors from more than one country. While the frequency of multi-institutional collaboration was the same in US and European studies, European ecologists collaborated with researchers from other countries much more frequently (27 percent of the papers) as compared to the US ecologists (10 percent). The mean numbers of authors, institutions, and countries per paper were 2.8 (± 1.6), 1.6 (± 0.9), and 1.2 (± 0.5), respectively. The average number of authors per paper was slightly higher in European studies (3.1 ± 1.8) than in US studies (2.5 ± 1.3). Authors represented more than one biological field (as indicated by the names of their departments of affiliation) in 18 percent of the papers, and the frequency of interdisciplinary collaboration was similar in US and European studies (18.3 percent and 17.7 percent, respectively).

The mean annual citation rate of the papers was 2.4 (± 2.3), and self-citations accounted for 25 percent of all citations. Overall, no differences were found in annual citation rates between US and European authors (US: 2.6 ± 0.16; European: 2.3 ± 0.10; F = 1.21, df = 1, P = 0.271), but annual self-citation rates were found to be significantly lower for papers authored by Americans than for those by Europeans (US: 0.56 ± 0.03; European: 0.63 ± 0.04; F = 5.09, df = 1, P = 0.024). When self-citations were excluded from the analysis, the annual citation rates of papers by US authors were significantly higher than those of Europeans (US: 2.01 ± 0.14; European: 1.68 ± 0.08; F = 4.82, df = 1, P = 0.028).

Annual citation rates correlated positively with the number of authors, whether self-citations were included (r = 0.16, P = 0.0001) or excluded (r = 0.09, P = 0.009; figure 1), although in the latter case the relationship was very weak. Pearson's correlation coefficient between annual self-citations and the number of authors was also significantly positive (r = 0.274, P = 0.0001; figure 1). Annual citation rates increased statistically significantly with the number of authors for both US (r = 0.220, P = 0.0001) and European studies (r = 0.133, P = 0.0148). When self-citations were excluded, however, the positive relationship between number of authors and citation rate was significant for US studies only (r = 0.166, P = 0.0016).

Neither the number of countries nor the number of biological fields affected the annual citation rates of papers by either European or US ecologists (table 1). However, the number of institutions had a statistically significant effect on the annual citation rates of all studies and European studies, and there was a significant interaction between the number of institutions and the number of biological fields involved in the collaboration in all the analyses (table 1). The number of biological fields increased citation rates only when multiple institutions were involved in the collaboration (figure 2). On the other hand, when only one institution was involved, the number of biological fields decreased citation rates (figure 2). The level of collaboration (domestic in-house, domestic multi-institutional, or international) did not affect annual citation rates (all papers: F = 1.21, df = 2, P = 0.298; US: F = 0.77, df = 2, P = 0.462; Europe: F = 0.27, df = 2, P = 0.761; figure 3).

We found that US ecologists cite papers written by their compatriots (69.8 percent of ISI citations) more frequently than those by European ecologists (15.5 percent) (χ² = 18.6, df = 1, P = 0.0001). European ecologists, on the other hand, were found to cite US (47.1 percent) and European papers (36.4 percent) with nearly equal frequency (χ² = 1.17, df = 1, P = 0.280).

**Discussion and conclusions**

A vast majority of the papers examined were multiauthored, indicating that scientific collaboration plays an important role in ecology. Multi-institutional and international collaboration was also common, and the percentage of internationally authored articles in *Oecologia* was similar to or higher than the percentages previously reported for biology (Moed et al. 1991, Luukkonen et al. 1992) and freshwater ecology (Resh and Yamamoto 1994). In accordance with previous studies in ecology (Leimu and Koricheva 2005) and in other disciplines (Abt 1984, Glänzel 2002), we found that citation rates of ecological papers increased with the number of authors, and
this increase was especially pronounced when the number of authors exceeded four (figure 1). For the European studies, this relationship was simply the result of an increase in the number of self-citations in multi-authored publications (cf. Herbert 1995). In the US studies, on the other hand, the correlation between citation rates and number of authors remained significant after self-citations were excluded from the analysis. The higher citation rates of multi-authored papers may be due to higher quality of the collaborative research, to enhanced dissemination in the research community through the personal communications of many authors, or both (Aksnes 2003, Goldfinch et al. 2003).

When self-citations were excluded from the analysis, and variation in the number of authors was accounted for by means of ANCOVA, the benefits of collaboration in terms of increased citation rates were relatively minor and did not differ among various forms of collaboration (in-house, domestic, and international). Perhaps the most interesting and intriguing finding of our study, which was true for both US and European papers, is the interactive effect of multi-institutional and interdisciplinary collaboration on citation rates. We found that interdisciplinary collaboration enhances the citation rates of ecological studies only if more than two institutions are involved. Collaboration between departments within the same institution, on the other hand, significantly reduces citation rates compared with those of research conducted within the same department. A somewhat similar phenomenon at the institutional level has recently been reported by Goldfinch and colleagues (2003), who found that an increase in the number of domestic institutions involved in collaboration reduced the citation rates of articles by scientists from New Zealand. Taken together, these findings suggest that collaboration with one’s nearest neighbors (a kind of “scientific inbreeding”) may actually reduce the impact and visibility of the resulting publications.

Interestingly, although international collaboration has been viewed as an especially important prerequisite of high-impact research (Narin et al. 1991, Aksnes 2003), we found that the number of countries involved in the collaboration had no significant impact on the annual citation rates of either European or US ecological articles. It thus seems that international collaboration does not markedly enhance the scientific impact of ecological papers published in Oecologia. Previous studies that have reported higher citation rates for internationally authored papers were usually restricted to studies conducted within a single country, but included publications in different journals (Narin et al. 1991, Katz and Hicks 1997, Rousseau 2001, Aksnes 2003, Goldfinch et al. 2003). It has been shown that in several countries internationally coauthored papers are published in journals with different impact factors from those that publish domestic papers (Glänzel 2001). The different citation rates previously reported for internationally and nationally authored papers could thus be due to these studies’ publication in different journals; our study, on the other hand, demonstrates that within a single specific journal there may be no significant difference in citation rates between the two categories of studies. The observed lack of benefits of international collaboration may also be partly due to the general globalization of science. Scientists from different countries are nowadays more closely connected, and the availability and exchange of information and knowledge continue to expand. As differences have decreased between the scientific impact of nations (King 2004), the effect of international collaboration may have diminished as well. It has been shown, for instance, that in the

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Note: Results are from ANCOVA (analysis of covariance) with number of authors as a covariate; self-citations are excluded from the analysis.
early 1980s, internationally coauthored articles received significantly more citations than domestic articles, but in the late 1990s, international collaboration increased citation rates compared with those of domestic collaboration only when more than three authors were involved (Persson et al. 2004). Since our data set consists only of recent papers, it is not possible to test whether the importance of international collaboration has diminished in recent years in ecology as well.

On average, European ecologists seem to be more collaborative than US researchers: the proportion of multiauthored papers, the average number of authors per paper, and especially the proportion of internationally coauthored papers were higher for European studies than for US ones. This is as expected; researchers from smaller countries are assumed to be in greater need of collaboration (Goldfinch et al. 2003). However, the greater collaboration efforts of European ecologists do not translate into larger benefits in terms of increased citation rates of their articles as compared with those produced by the American researchers. On the contrary, US ecologists seem to benefit from cooperation more than European ecologists do; the citation rate of the US papers was positively correlated with the number of authors and tended to be higher for internationally authored papers (figure 3).

In agreement with our previous study (Leimu and Koricheva 2005), we also found that studies by US authors were more frequently cited on average than those by European ecologists. This was not due to a higher proportion of self-citations in US studies; on the contrary, papers by US authors received fewer self-citations than those by Europeans. On the other hand, we found that US ecologists preferentially cite US papers, whereas European ecologists cite US and European authors equally often (cf. Moller 1990, Wardle 1995). Two alternative explanations of this pattern are possible. Either citation practices of US researchers are parochial and inflate the citation rates of US papers, given the large US share of publications (King 2004), or papers by US authors are of higher quality, which is recognized by US ecologists, whereas it is the European ecologists who are parochial as they frequently cite the inferior European papers. We were unable to distinguish between these alternatives, because judging the quality of the studies is problematic, and this topic is beyond the scope of the current study.

Overall, our study has shown that scientific collaboration in ecology has a fairly minor, and not always positive, effect on the citation rates of the resulting publications. Similar conclusions have been reached by studies in several other fields (Herbertz and Müller-Hill 1995, Avkiran 1997). On the other hand, Tregenza (2002) has shown that single-authored papers have a higher probability of being rejected by ecological journals than multi-authored ones. Oecologia is one of the major ecological journals and has a rigorous refereeing process, with only 20 percent of the submitted manuscripts being accepted for publication. It is thus possible that ecological studies involving different degrees of collaboration vary in quality at the submission stage, but that no differential in quality remains after the refereeing process. Furthermore, citation rates measure only scientific utility and not other aspects of study quality, such as methodological quality and originality. Future studies should examine the impact of scientific collaboration in ecology on these aspects as well. Until evidence of such an impact is found, however, decisionmakers should be cautious about assigning too much importance to the presence of scientific collaboration in the allocation of research funds.
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