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The sustainability publication gap and its implications

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Scientific articles and journals represent a knowledge network, and the distribution of articles among journals with different impact factors highlight a structure of the network. We found a large gap in the publication pattern of sustainability with research published in either high or low impact factor journals, but not middle-range impact factor outlets. This distribution stands in contrast to established disciplines, which maintain a continuous gradient across low to high impact factor journals. The bi-modal publication pattern of sustainability may reflect the variation in the significance of the topics addressed by sustainability researchers or the youthful stage of sustainability as a scientific field. The sustainability publication gap may hamper communication among sustainability scientists and delay the consolidation of the field. Simultaneously, it may assist sustainability from becoming a research silo, nurturing and strengthening the integrative character of its research.

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Introduction

Sustainability science is a field of study focusing on problems of meeting fundamental human needs for present and future generations while simultaneously preserving the Earth's life-support systems [1]. It has emerged over the past 30 years with its knowledge network growing at a rapid pace, measured by number of research units, journals or journal sections, and degree-granting programs devoted to it [2•]. More than 100 000 different authors have penned research on various sustainability topics, published at a rate of about 3000 articles a year in a broad range of journals [3–5]. The number of journals focused on sustainability themes has grown at a similar rate [2]. Some of the central journals of the discipline have grown in research diversity. *Sustainability Science*, for example, has more than doubled the original half dozen research specialty areas contributing to the journal since its inception in 2006 [6•]. The *Proceedings of the National Academy of Sciences*, started the Sustainability Science Section in 2006 with 52 submitted papers and 26 published. In 2018, it had 320 submissions and 82 published representing a sixfold increase in submissions and threefold increase in published papers.

This growth notwithstanding, the field remains in a youthful stage of development, comprising differing visions of its practice and ties to decision-making and solutions [7–11]. These differences result in multiple pathways toward the same overall objectives, creating synergies among its practitioners but not necessarily coalescing the pathways into a formal, unified field of study or discipline [12]. Indeed, the need of an integrated science addressing the social-environmental problems of sustainability that does not 'silo' itself as formal disciplines have historically done has been a clarion call among many sustainability practitioners and educators [13,14,15••,16••].

Scientific journals are the main medium of exchange among researchers and the repository of the network of knowledge used by students and practitioners. Publication patterns describe the topography of the network of knowledge and suggest the functionality of a discipline. The characteristics of the network can help identify current challenges or strengths for a given field. The distribution of articles among these different types of journals is what we call the distribution pattern of articles for fields of study and disciplines. Our primary question is whether this pattern differs between the emerging field of sustainability and other, established science disciplines.

Publication pattern refers to the distribution of articles among journals with different citation impact and, in some cases, readership. As we reveal below, there is a substantial difference in publication patterns between sustainability research and that within the long-standing disciplines of biology, chemistry, ecology, physics, and psychology. Why do these distinctions exist and do they infer significant insights about the structure of the sustainability knowledge network? Do they reflect the youthful stage of sustainability science and will change to publication patterns consistent with the other field of study as the sustainability field matures?

Like it or not, different journals maintain metrics addressing the citation attention given to them, including the impact factor and eigenvector [17]. Of these, the impact factor refers to the average number of citations received per paper published in that journal during the two preceding years and has historically been the most used metric of the two [18]. Journals with high impact factors tend to be highly selective, leaning towards articles with novel ideas and potential transformative results, or in some cases, reviews of fields of research. These interdisciplinary outlets, such as *Science*, *Nature*, and *Proceedings of the National Academy of Sciences* are highly restrictive in the space given to individual articles, often placing the base data and methods, critical for evaluation of replication, in online supplementary formats.

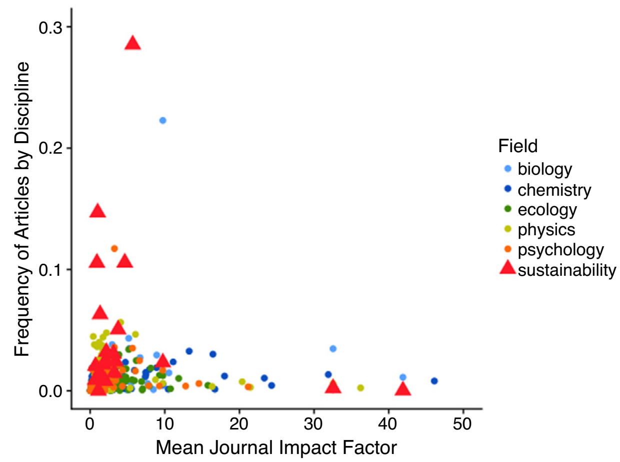
The majority of the research output in science, however, is published in journals of medium to low impact factors aimed at specialized audiences. Among the articles in these outlets, a significant number provide the data and analytics that serve as the foundation materials that support or refute the ideas proposed or first reported in the high impact journals. In these types of journals, space is provided for in-depth assessment of data, methods, and experimental details that serve the needs of other experts and facilitate research replication.

The gap analysis of this study was based on 2013 and 2014 Journal Citation Report data. Mean impact factor and mean number of articles were calculated for 89 journals in biology, 150 journals in chemistry, 150 journals in ecology, 79 journals in physics, 82 journals in psychology, and 22 journals in sustainability. In addition to evaluating disciplinary journals, we assessed the representation of each discipline in three high-impact multi-disciplinary journals, *Nature*, *Science*, and *Proceedings of the National Academy of Sciences*. We recorded all articles published in those three journals for every issue in each month of 2013 and 2014 and the discipline they fell under and then calculated the mean over the two years. The temporal trends reported in this paper were based on the impact factor of sustainability journals and that of high-impact journals for the period 1997–2017.

Patterns of publication

In accordance with the citation data [19], sustainability research displays a publication pattern that is different from that in biology, chemistry, ecology, physics, and psychology (Figure 1). The established disciplines show a continuous gradient in the distribution of their articles among journals with different impact factors (IFs). The majority of the articles in the long-standing research fields were published in journals with IFs not exceeding 6, a sizable fraction in journals with IFs above 6 but no higher than 30, and only a small fraction in journals with IFs above 30. The latter outlets are those on which the media keep an especially close eye.

Figure 1



Comparison between sustainability and four science disciplines regarding the distribution of articles among journals ranked according to their impact factor. The X axis shows the impact factor of each journal. The Y axis depicts the frequency of articles published in each journal, calculated as the proportion of the total number of articles in the discipline that were published in 2013 and 2014 in a given journal.

The publication pattern of sustainability differs substantially from the comparative science disciplines in question. Interestingly, the new sustainability field is represented in high-impact (IFs above 30) journals in a similar magnitude to the established sciences, but the large majority of its research resides in journals of relatively low IFs (below 6). An obvious gap exists for the sustainability research network in mid-range impact journals (Figure 1). Overall, across biology, chemistry, ecology, physics, and psychology, the mean percentage of articles published in journals with an impact factor of ≤ 6 was 83% (95% CI = 74–92%). Sustainability, with 97% of articles published in journals with impact factors ≤ 6, significantly falls above this interval.

Another approach to identifying differences in the publication patterns between sustainability and established disciplines involves evaluating the distribution of journals categorized by their impact factors. Each cell in Table 1 has the number of journals for each discipline that falls into one of three IFs categories: ≤ 6, >6 and ≤ 30 and >30 and ≤ 50. The expected values for sustainability were calculated by

Table 1

Comparison between sustainability and five established disciplines in terms of the allocation of disciplinary journals among three categories of impact factors. Each cell contains the observed frequency of journals by discipline categorized by impact factor. The numbers in bins refer to the number of journals in each discipline with impact factors in three ranges ≤6, >6 and ≤30 and >30 and ≤50. A Chi Square goodness of fit analysis comparing the observed and expected patterns for sustainability showed that the expected frequencies had a poor fit with the observed frequencies ($v = 2$, $X^2 = 71.323$, $X^2_{0.05,2} = 5.991$, $p < 0.001$). The expected allocation of journals for sustainability was hypothesized as the mean of the observed values for the other four disciplines. All data (impact factor and journal frequency) are taken from 2013 and 2014 means

Bins (*impact factor*)	Biology	Ecology	Chemistry	Physics	Psychology	Sustainability (*observed frequency*)
≤6	80	137	132	70	72	19
>6 and ≤30	7	11	14	6	8	1
>30 and ≤50	2	2	4	3	2	2

the average of the values for the first five disciplines. A chi-squared goodness of fit test revealed that sustainability was significantly different with regard to journal distribution ($v = 2$, $X^2 = 71.323$, $X^2_{0.05,2} = 5.991$, $p < 0.001$).

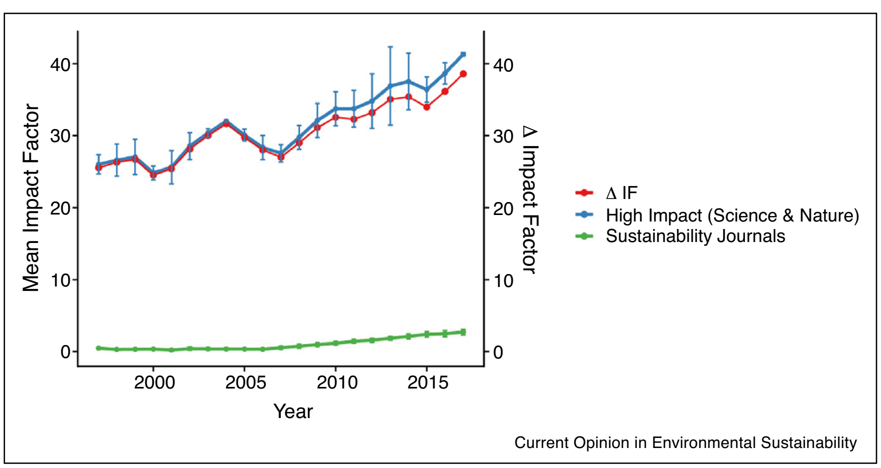
The sustainability gap between sustainability journals and high-impact journals did not close during the period from 1997 to 2017 (Figure 2). Although the impact factor of sustainability journals increased during that period, the gap with the high-impact journals expanded. The impact factor of most scientific journals grew during that period as a result of various factors, including the growth in the number of references per article and the number of reviews versus data papers [20].

Causes of the network pattern of sustainability publications

Why might the distinctive bimodal publication pattern for sustainability exist? The concentration of sustainability in high impact-factor journals likely reflects the significance of sustainability problems, among the most serious challenges of this generation, especially in light of the totality of the human impact on the Earth system in this, the Anthropocene [21••,22]. Several of the indicators of the condition of our planet are alarming [22,23••]. Moreover, future demand of ecosystem services, such as food production and water, is rapidly increasing [24,25], creating further pressure on Earth's life-supporting systems [26]. The significance of the problem leverages attention within the highest impact-factor journals [3,8], which have the potential for galvanizing research communities to take on the problem. This significance and potential are further registered by the Sustainability Science 'section' of the *Proceedings of the National Academy of Sciences* (U.S.) and the new journal, *Nature Sustainability*.

The majority of sustainability journals, however, maintain relatively low IFs and these outlets host the preponderance of sustainability articles. No journals devoted explicitly to sustainability research maintain mid-range IFs (6–30). This circumstance may reflect that the sustainability field has had insufficient time to mature to a stage, in which a large number of researchers across the many areas of sustainability science identify core outlets

Figure 2



Trend of the mean impact factor for sustainability journals and the average of the high-impact journals *Nature* and *Science*. Although the average impact factor for sustainability journals increased during the period, the gap with the high-impact factors also increased. Vertical bars represent the Standard Error (SE = SD/*N*). Sustainability journals have a much smaller SE because of the larger *N* in contrast with the *N* = 2 for *Nature* and *Science*.

through their publication choices. Core journals are commonly associated with societies or organizations recognized as the foci of research fields. It is not yet clear that such entities have emerged for sustainability science at large, perhaps a reflection of the next issue. Different visions of sustainability research exist, ranging from basic science to informed practice for engineering, managerial, and policy solutions. In addition, there is a large 'disciplinary' range of researchers engaged in sustainability themes, including the biophysical, social, and engineering sciences. The resulting complexity of specific interests and approaches may be fostering the development of a number of societies or organizations and associated journals that serve clusters of research interests underneath the sustainability umbrella. Examples include the numerous focused sustainability journals, such as *Current Opinion in Environmental Sustainability* or the *International Journal of Sustainable Engineering*. The breadth of the expertise needed to tackle the major sustainability issues may impede these research clusters to merge under a few common journals.

Conclusions: does the sustainability publication gap require closing?

Regardless of the relative merits of these interpretations, the gap in the network structure of sustainability publications would appear to hold important implications for the future of sustainability as a research field. The spread of articles among many low-impact journals may make communication among sustainability scientists difficult. If sustainability were to consolidate into a research field akin to the established science fields, the absence of recognized core journals with mid-range citation averages would appear to serve as an impediment.

Alternatively, sustainability problems require an integrated, human-environment science approach, typically addressed through the lens of the social-environment system. Putting the parts of this system back together is intended to complement the understanding gained through existing disciplines. Perhaps the vigor of integration in sustainability is maintained by the diversity of its many parts and research framings, consistent with the many outlets devoted to them. The emergence of core journals may lead to the very 'silos' of knowledge that sustainability attempts to overcome by the way of integrated understanding.

Pros and cons exist, therefore, regarding the closing of the publication gap. Finally, the costs and benefits of these alternative paths in terms of maintaining a scientific community engaged with its own identity or a dispersed group taking advantage of hybrid vigor are difficult to assess but remain an open challenge for sustainability as a critical field of inquiry in the Anthropocene.

Conflict of interest statement

Nothing declared.

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