Journal of Experimental Marine Biology and Ecology 377 (2009) 93–100

Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Terrestrial ecologists ignore aquatic literature: Asymmetry in citation breadth in ecological publications and implications for generality and progress in ecology☆

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ARTICLE INFO

Article history:
Received 27 June 2009
Accepted 29 June 2009

Keywords:
Citation asymmetry
Freshwater
Generality in ecology
Literature survey
Marine
Terrestrial

ABSTRACT

The search for generality in ecology should include assessing the influence of studies done in one system on those done in other systems. Assuming generality is reflected in citation patterns, we analyzed frequencies of terrestrial, marine, and freshwater citations in papers categorized as terrestrial, marine and freshwater in high-impact "general" ecological journals. Citation frequencies were strikingly asymmetric. Aquatic researchers cited terrestrial papers ~10 times more often than the reverse, implying uneven cross-fertilization of information between aquatic and terrestrial ecologists. Comparisons between citation frequencies in the early 1980s and the early 2000s for two of the seven journals yielded similar results. Summing across all journals, 60% of all research papers ($n=5824$) published in these journals in 2002–2006 were terrestrial vs. 9% freshwater and 8% marine. Since total numbers of terrestrial and aquatic ecologists are more similar than these proportions suggest, the representation of publications by habitat in "general" ecological journals appears disproportional and unrepresentative of the ecological science community at large. Such asymmetries are a concern because (1) aquatic and terrestrial systems can be tightly integrated, (2) pressure for across-system understanding to meet the challenge of climate change is increasing, (3) citation asymmetry implies barriers to among-system flow of understanding, thus (4) impeding scientific and societal progress. Changing this imbalance likely depends on a bottom-up approach originating from the ecological community, through pressure on societies, journals, editors and reviewers.

1. Introduction

A prime motivation in research is to ask if one's results are applicable to systems beyond the one of focus. Given the immense diversity of ecological systems, answering this question is key to advancing our understanding of community and ecosystem functioning. In community and ecosystem ecology, however, the search for generality often seems hindered by a relative lack of awareness of progress in other systems. For example, several authors have commented on the gap in communication between scientists working in aquatic and terrestrial habitats (e.g., Steele, 1991; Chase, 2000; Stergiou and Browman, 2005a; Richardson and Poloczanska, 2008). In some respects, this terrestrial vs. aquatic "controversy" is based on real and important contrasts. Terrestrial and aquatic environments are inherently different, as reflected in several aspects of the ecology of the communities and organisms within them (Carr et al., 2003). However, most fundamental ecological processes are shared among systems. Further, contrary to the opinions of some (e.g., Richardson and Poloczanska, 2008), much of our conceptual framework applies across all systems with ideas flowing in both directions between aquatic and terrestrial arenas (e.g., Halley, 2005; Paine, 2005; Raffaelli et al., 2005).

But what is generality, exactly? As implied by the above-cited controversy, is it the extent to which results in one habitat apply to systems in other habitats? That is, do outcomes obtained in a study conducted in a terrestrial environment contribute to inductively reasoned inferences about the dynamics of systems occurring in the other major habitat types, marine or freshwater? We define this as "habitat" generality. Or is generality more theoretical, in which model results apply to a broad range of populations, communities or ecosystems? "Theoretical" generality was one of a triumvirate of

☆ Editor's Note: This paper represents the complete version of a manuscript that was shortened and published as a "peer-reviewed" letter to the editor in *Frontiers in Ecology and the Environment* (2009, Vol 7:182–183). Having read and commented upon the original version, this Editor noted that key pieces had been deleted in the shorter version and encouraged the authors to submit the manuscript in its original form to JEMBE. The issues discussed are important and pertinent to all ecological research, be it marine, aquatic or terrestrial. S.E. Shumway.

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doi:10.1016/j.jembe.2009.06.024

Table 1
Ranking of "impact factors" of top ecological journals, 2003–2007.

Journal	ISI CI Mean ± 1SEM	ISI CI range	AI	Category
Trends in Ecology & Evolution	13.85 ± 0.50	12.44–14.96	8.98	Broad
Ann. Rev. of Ecology, Evolution & Systematics	9.17 ± 0.76	6.18–10.34	8.39	Review
Ecological Monographs	5.98 ± 0.69	4.79–8.12	3.98	General
Ecology Letters	5.82 ± 0.88	3.91–8.20	3.69	General
Molecular Ecology	5.11 ± 0.71	3.87–5.17	2.01	Specialized
American Naturalist	4.44 ± 0.10	4.06–4.66	2.98	General
Ecology	4.38 ± 0.21	3.70–4.82	2.84	General
Frontiers in Ecology and Evolution[a]	4.30 ± 0.30	3.36–4.84	2.56	Broad
Journal of Applied Ecology	3.96 ± 0.30	3.21–4.59	1.76	Specialized
Journal of Ecology	3.83 ± 0.31	2.83–4.42	1.97	General
Ecological Applications	3.40 ± 0.16	2.85–3.80	2.29	Specialized
Journal of Animal Ecology	3.34 ± 0.14	2.84–3.75	1.94	General
Ecosystems	3.12 ± 0.14	2.68–3.46	2.16	General
Oecologia	3.07 ± 0.07	2.90–3.33	1.81	General
Oikos	2.97 ± 0.22	2.14–3.38	1.72	General
Functional Ecology	2.96 ± 0.19	2.35–3.42	1.59	General
Marine Ecology Progress Series	2.27 ± 0.08	2.05–2.55	1.15	Specialized
J. of North American Benthological Society	2.04 ± 0.15	1.58–2.37	1.20	Specialized
J. of Experimental Marine Biology & Ecology	1.70 ± 0.06	1.59–1.92	0.83	Specialized

Based on ISI citation index (Thomson Reuters Inc.), with Article Influence (AI) Index (http://www.eigenfactor.org) included for comparison. Categories: Broad = summaries of new developments and ideas; Review = reviews of current issues; General = primary research journals for all areas of ecology; Specialized = primary research journals for specific areas of ecology. Journals highlighted in bold italics are the seven surveyed in this study. Italicized journals had too few aquatic papers to allow statistical analysis. Table first appeared as Webtable 1 in supplementary material for article in *Frontiers in Ecology and the Environment* 7:182-183, 2009.
[a] Publication began in 2004.

characteristics (generality, precision, and realism) identified decades ago by Levins (1966) as a tradeoff that constrained the effects of model builders, with the asserted limitation that particular types of models (analytical, simulations) could satisfy two but not all three of these traits. Generality could also be "geographic," such that results obtained in a particular type of ecosystem in one geographic region apply to the same type of ecosystems located in different geographic regions. Another possible form of generality is conceptual, in which ecological concepts such as top-down, bottom-up, trophic cascade, positive interactions and intermediate disturbance provide a deductive framework for investigating patterns and processes that may operate across broad suites of individual systems (e.g., Chase, 2000).

Here we focus on generality as reflected in citation patterns of terrestrial, marine and freshwater papers in publications categorized into these three groups. Our interest in examining habitat generality was prompted by personal experience and comments of colleagues (see e.g., Underwood, 2005) that reviewers often criticized submissions of marine ecological papers to general journals as not being of sufficiently broad interest; they were "too marine." The usual guidance was to demonstrate that results were of interest to a non-marine audience, usually understood as terrestrial.

Such comments made us wonder if non-marine authors received similar criticisms. In lieu of directly surveying authors, a difficult and relatively subjective method, we approached this question through a literature survey. Assuming that the extent of comparison of one's results would be reflected in the frequency of citations of papers from other systems, and using papers sampled from general ecological journals, we estimated the proportions of marine, freshwater, and terrestrial citations in marine, freshwater and terrestrial publications in community and ecosystem ecology. To assess the publication scenario against which these citation frequencies occur, we also summarized the frequencies of all terrestrial, marine, freshwater papers in each journal. Of course, one would expect that, correcting for citations that may largely be independent of habitat (methodological, conceptual/theoretical, reviews/books, and theses, collectively termed "other"), most citations in a terrestrial (or marine or freshwater) paper, for example, will be terrestrial (or marine or freshwater). But if all authors are being urged to emphasize generality or breadth independently of habitat, then the proportion of citations of papers from habitats other than the subject of the paper should be similar regardless of whether the paper was terrestrial, marine or freshwater.

2. Methods

We surveyed ten general ecological journals having the highest impact factors in which community and ecosystem ecology papers were frequently published. Our primary measure of impact was the ISI Impact factor index (http://www.isiwebofknowledge.com), averaged over 2003–2007 (Table 1). For comparison we also show a second measure, the eigenfactor index (Table 1; http://www.eigenfactor.org). Journals that specialize in reviews, applied papers, discussion, perspectives, ideas, and current events were excluded (e.g., *Trends in Ecology and Evolution*, *Frontiers in Ecology and Evolution*, *Advances in Ecological Research*, *Annual Review of Ecology*, *Evolution and Systematics*, *Ecological Applications*, *Journal of Applied Ecology*). On this basis, the top ten "general" journals were, in order, *Ecological Monographs*, *Ecology Letters*, *American Naturalist*, *Ecology*, *Journal of Ecology*, *Journal of Animal Ecology*, *Ecosystems*, *Oecologia*, *Oikos*, and *Functional Ecology* (Table 1).

Community and ecosystem papers were defined as those involving more than a single species, that examined species interactions or how species assemblages were influenced by the physical, chemical or biotic environment, and that dealt with at least one of the relevant conceptual topics (Table 2). When possible, the title and keywords of the papers

Table 2
Summary of literature survey.

Period	Habitat of source paper	Journal							
		American Naturalist	Ecology Letters	Ecological Monographs	Ecology	Ecosystems	Oecologia	Oikos	Total
Recent	Terrestrial	62 (28)	57 (7)	41 (35)	49 (0)	48 (0)	47 (0)	55 (2)	359 (72)
	Freshwater	15 (7)	21 (11)	6 (5)	24 (4)	14 (2)	23 (11)	24 (10)	127 (50)
	Marine	7 (4)	27 (11)	18 (14)	23 (5)	15 (10)	28 (16)	19 (12)	137 (72)
Past	Terrestrial	28 (6)	na	na	53 (0)	na	na	na	81 (6)
	Freshwater	6 (2)	na	na	32 (14)	na	na	na	38 (16)
	Marine	11 (6)	na	na	29 (19)	na	na	na	40 (25)
	Total	129 (53)	105 (29)	66 (54)	215 (42)	82 (12)	98 (27)	99 (24)	793 (241)

Data are number of papers in each category, with number of non-randomly selected papers shown in parentheses. Periods were 2002–2006 (recent) and 1980–85 (past). Conceptual categories included in survey: biodiversity, bottom-up, climate change, community assembly, community dynamics, competition, connectivity, dispersal, disturbance, disease, diversity, ecosystem engineers, environmental stress, facilitation, functional role of diversity, functional response, food web, herbivory, intermediate disturbance, indirect effects, island biogeography, interaction strength, interaction web, introductions, invasions, keystone species, keystone predation, meta-community, meta-ecosystem, numerical response, parasitism, predation, productivity, resilience, species richness, stability, source-sink, succession, top-down, tritrophic interactions, and trophic cascade. Table is modified from Webtable 5 in supplementary material for article in *Frontiers in Ecology and the Environment* 7:182-183, 2009.