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Bridging the gap in marine and terrestrial studies

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Abstract. Ecologists are interested in understanding natural phenomena and strive to make comparisons across systems to better understand broad ecological processes and patterns. Recent reviews showcased how marine and terrestrial ecologists (as an example of two isolated disciplines) can benefit from sharing information. Here, a literature review shows that marine studies often lack the generality needed to bridge the often observed gap between theory developed in marine and terrestrial systems. In order to stimulate constructive comparisons across systems, we discuss potential reasons for this lower generality, with the goal of more broadly understanding ecological processes and patterns.

Key words: generality; marine ecology; terrestrial ecology.

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The targets of question-driven science are mechanisms that provide a framework for understanding natural phenomena, regardless of the study system. We agree with the recent forum from a group of ecologists suggesting that a better synthesis of research from marine and terrestrial systems is required to better understand ecological paradigms (Rotjan and Idjadi 2013). This is an old cry (e.g., Stergiou and Browman 2005*a*, Menge et al. 2009), however little progress has been made in the last 30 years (Rotjan and Idjadi 2013). Here we propose mechanisms behind the lack of progress in bringing these fields together as we consider this an important topic that has consequences and should be addressed at 3 different levels: research, education, and funding agencies. In this forum we propose that the challenge resides with marine scientists.

We believe a major problem that will arise when attempting to overcome the perceived barrier between marine and terrestrial studies resides in the different approaches to doing science. We hypothesize that the reason for the low number of marine studies in general ecology journals (Stergiou and Browman 2005*b*, Menge et al. 2009) could be due to a narrower approach when showcasing the research or different motivation behind the work. Of course, alternative hypotheses abound, including the historical perspective that general ecology journals have traditionally focused on terrestrial systems and are thus biased towards those studies. To address this, we contrasted the generality of topics in terrestrial ecology papers published in journals exclusive to terrestrial systems with marine ecology papers published in journals exclusive to marine systems.

To estimate the generality of the paper topic, we used the line of first mention of the study organism as a proxy to measure a paper's generality (Bonnet et al. 2002). In general, a paper that focuses on processes or general ecological concepts will introduce the study

species late in the introduction (often close to the specific study objectives). In taxon-oriented journals the line of first mention occurs sooner than in concept-oriented journals (Bonnet et al. 2002). Papers that quickly introduce the study system tend to have a more narrow conceptual focus and could have a harder time appealing to broader audiences. The long-term outcome results in these papers being poorly cited and not stimulating broad research in other systems in the future (Menge et al. 2009).

We selected three journals that publish papers in ecology regardless of the system in which the study was done (*Ecology*, 5-yr impact factor [IF] = 6.007; *Oecologia*, IF = 3.888; and *Oikos*, IF = 3.604), three journals specific to marine systems (*Journal of Experimental Marine Biology and Ecology*, IF = 2.395; *Marine Biology*, IF = 2.471; and *Marine Ecology Progress Series*, IF = 3.086) and three centered on terrestrial environments (*Journal of Ecology*, IF = 6.020; *Journal of Arid Environments*, IF = 2.135; and *Journal of Vegetation Science*, IF = 3.027). Twenty papers of each field-specific journal published in the last 2 years were haphazardly selected and 40 papers were haphazardly selected from each general journal, where 20 were studies done in coastal or marine environments, and 20 papers were conducted on terrestrial systems. We analyzed the data with a mixed model where environment (marine or terrestrial) and journal category (general or specific) were fixed factors and journal name was a random factor using restricted maximum likelihood estimates (REML; Fletcher and Underwood 2002). Papers in general journals and journals specific to terrestrial studies started their introduction with a broader conceptual background and more focused on processes (Fig. 1). These papers introduced the study species between lines 50 and 60, which corresponds to the third or fourth paragraph of the introduction. However, papers in journals specific to marine systems were taxon-specific, introducing the study organism within the first two paragraphs of the introduction. In specific journals, the subject species was introduced in the first sentence of 22 marine studies compared to 8 terrestrial studies.

In both fields, we believe scientists are asking questions driven by inquiry-based research (e.g., Raffaeli et al. 2005). So why do terrestrial ecologists write process-focused papers and marine scientists do not? There are several possible explanations for this pattern (Table 1). Interestingly, marine papers published in general ecology journals have a broad conceptual introduction (Fig. 1), so why do marine scientists choose not to present conceptual introductions in marine journals? The reason behind it could be cultural, and there is a different perception by researchers, reviewers and editors of how science is showcased (Table 1). Perhaps marine scientists perceive that a paper is less likely to be accepted in a marine journal if it is generally focused, or that the paper would have less appeal to their marine ecology peers. Finally, working on marine systems could be viewed as logistically challenging to a degree that it requires specific journals that can present or interest scientists on those particular systems. Regardless of the reason, scientists in general and marine ecologists in particular, have too often fallen for an "us vs. them" view which hampers progress (Menge et al. 2009, Rotjan and Idjadi 2013). Potential excuses such as the age of the field or the idea

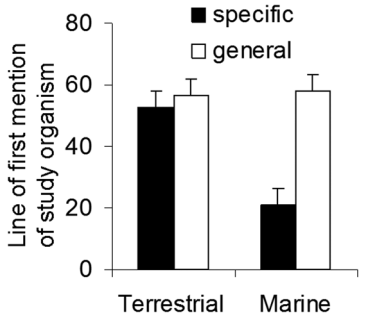

Fig. 1. Line of first mention of the study organism for 240 papers published between 2010 and 2012 in general ecology journals (*Ecology, Oikos, Oecologia*) and terrestrial (*Journal of Arid Environments, Journal of Ecology, Journal of Vegetation Science*) and marine (*Journal of Experimental Marine Biology and Ecology, Marine Ecology Progress Series, Marine Biology*) journals. In the mixed model, journal name accounted for 2% of the variation and there were strong effects of Environment (E) ($F = 14.6$, $P < 0.0001$) and Journal generality (general or specific) (G) ($F = 88.34$, $P < 0.0001$). There was a strong E × G interaction ($F = 19.12$, $P < 0.0001$), where journals specific to marine ecology mentioned the study organism before couching the study in a general framework.

Table 1. Hypotheses driving the lower generality in marine studies relative to terrestrial studies and their potential consequences.

Type	Description
Hypotheses	
Historical	Marine ecology has historically approached questions from a natural history perspective, whereas terrestrial ecology approaches questions from a conceptual perspective, in addition to focusing on natural history of particular systems.
Cultural	Marine ecology journal editors may more readily accept papers that introduce the system earlier than terrestrial ecology journal editors.
Terrestrial dominance	General ecology journals are biased towards publishing terrestrial papers.
Logistical feasibility	Terrestrial systems are more accessible than marine systems.
Consequences	
Funding	Scientists asking similar questions have to apply to different panels depending on the particular study system. Funding agencies have difficulty in categorizing "marine" habitats, in particular when dealing with intertidal, estuarine or marsh habitats.
Education	Narrow focus ostracizes other disciplines and ignores approaches to addressing questions. By splitting courses and graduate programs, young scientists start their careers with a narrow understanding of concepts in ecology.
Research	Universities and sub-disciplines often partition groups and research into terrestrial and marine. This partition may generate feedback into education, funding and perception from the general public.

that marine ecologists focus on the natural history should not be valid if we are working towards a synthetic framework of ecological systems (e.g., Paine 2005). Some of the great advances in ecology, such as intermediate disturbance hypothesis and island biogeography have benefited from applying the theory to both marine and terrestrial systems (e.g., Hanski and Gilpin 1991, Whittaker et al. 2001, Shea et al. 2004) and comparing how processes act similarly and differently in various systems (Webb 2012). The end product is a constant re-evaluation of the theory while advancing our understanding of specific systems. Yet even scientific meetings ostracize one or the other field. For example only 6% (119 out of 1851 talks and posters) of the presentations at the 98th Annual Meeting of the Ecological Society of America in 2013 were based on marine systems. The figure was remarkably similar (6.9%, 90 out of 1210 presentations) at INTECOL 2013. Marine contributions are typically placed in specific sessions rather than sessions in line with their theoretical contribution. Probably because of this reason, marine scientists are often not interested in attending general meetings, but prefer instead to attend the American Society of Limnology and Oceanography meeting, for example. These hypotheses have a direct consequence in how ecologists conduct their work (Table 1) and present a major obstacle before any cross-system synthesis (sensu Rotjan and Idjadi 2013).

A second consequence of the observed lack of generality pattern could be affecting the way we educate scientists (Table 1). In trying to differentiate and highlight the unique characteristics of marine habitats, we could be excluding ourselves from general patterns in ecology. The number of marine examples relative to terrestrial examples in ecology textbooks is extremely low. We sampled three chapters from each of three books, ensuring the chapters were not concept-biased towards terrestrial specific concepts. We found 1marine example out of 40 in Ricklefs (1997, Chapters 10, 12, 18), 2 out of 46 examples in Krebs (2001, Chapters 12, 13, 14), and 2 out of 60 examples in Begon et al. (1990, Chapters 2, 14, 15). With an overall 5 examples out of a total of 186 examples being marine, there is a clear underrepresentation of marine studies in these general ecology journals. Alternatively, why is a course on "general ecology" focused on terrestrial systems, forcing the development of "marine ecology" courses? The attempt to provide better management of courses and academic programs has fueled discrepancies between the two research systems (marine and terrestrial). Yet this consequence could be easily avoided by synthesizing programs and courses.

The third consequence of the different approaches between marine and terrestrial scientists could be affecting the way funding agencies partition funds between terrestrial or marine systems (Table 1), instead of focusing on ecolog-

ical sub-disciplines or questions. For example, at the United States National Science Foundation, a proposal on the reproductive ecology of a freshwater fish would be submitted to the Ecology Panel, while exactly the same proposal using a marine fish species with similar traits has to be submitted to the Biological Oceanography panel. The two proposals would have different reviewers and even different chances of being funded independent of their quality. This polarization has the potential to segregate scientists merely on the salinity of the study system and not the more relevant question of theory (e.g., Menge et al. 2009). In Menge and colleagues' recent review (2009), data show that terrestrial papers are cited ten times more often in aquatic studies compared to the citation frequency of aquatic studies in terrestrial papers. Moreover, this breaking down of funding leaves intertidal and estuarine habitats in a grey area (e.g., Underwood 2005).

To provide a cohesive framework, scientific meetings, courses and journals often focus on one of these domains with danger residing in not acknowledging studies on systems outside the scope of the meeting, course or journal. We agree with Rotjan and Idjadi (2013); in order to broadly test a theory, we need to test it in multiple systems and see where it is supported and where it is not and this is the best way to advance the field of ecology. We hope to resolve the debate in an effort to consolidate and improve research and teaching efforts. The first step would be for marine scientists to follow the example of terrestrial ecologists and place their work in a broader context.

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