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Zen and the art of ecological synthesis

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Progress

Zen is a way of being that incorporates togetherness. Scientific syntheses similarly include aggregation and often acceptance of divergent elements such as data in different forms, multiple terminologies, meta-data, ecosystems and diverse concepts (Lortie 2014). Ecology and conservation biology are increasingly faced with demands and relevancy as global change rapidly accelerates (Balmaseda et al. 2013), and in many respects, both disciplines embody both zen and synthesis like few other (Barash 1973, Allendorf 1997). Ecology has always been the study of interrelations (Barash 1973) and thus zen in many respects. We continue to cross many collaboration and data thresholds (Hampton and Parker 2011, Hampton et al. 2013) that promote more effective examination of ecological relationships at larger scales. These advances including more open science and open data increase our capacity for syntheses (Wolkovich et al. 2012), but it is not always easy to 'see the entire university in our breakfast cereal' (Allendorf 1997) or our research. Systematic reviews and meta-analyses have a sound history in science (Rothstein 2015) and well-articulated guidelines (Higgins and Green 2011).

Frequently, these syntheses provide a single stop for the contemporary reader to assess the state of the art, efficacy, and research gaps for a discipline. Evidence-based commentaries in the public media commonly invoke synthesis findings from meta-analyses, and environmental scientists routinely support this paradigm at all levels of research and policy (<www.environmentalevidence.org>). The move from discussion of single studies to set of studies is a profoundly positive advance in defining scientific knowledge.

In Oikos, progress in this domain has been significant. A total of 71 meta-analyses have been published to date with a collective h-index of 28 at 37.8 citations per paper – Web of Science citation analytics October 2015 (Lortie 2015). Citations belie the true value of these syntheses in spite of significant increases in the number of meta-analyses published by Oikos (regression analysis publication count by year, linear fit, $r^2 = 0.46$, $p = 0.001$, $DF = 1$) or even increasing citations by year to this body of work (regression analysis citations by year, curvilinear fit, $r^2 = 0.33$, $p = 0.04$, $DF = 2$). A responsibility of every society journal in ecology should be to provide the substrate needed for many readers and audiences to assess progress within a subdiscipine of ecology, conservation, or environmental science using more than the 'serial single-study' knowledge approach. *We discuss one study at a time and sometimes fail to see the forest for the trees.* An instant opportunity to assess reach is available through the online tool impactstory (<www.impactstory.org>) using altmetrics (Piwowar 2013). These meta-analyses have been discussed/shared in nearly 900 geotagged events on twitter and other social media in 58 countries (Fig. 1). Many of the contributions are identified as highly cited and saved, and the citation-saves values correspond at approximately 3000 each. These values confirm the conventional estimates from the Web of Science analytics. More hopefully however, over 10% of these meta-analyses have been *discussed*. In Oikos, we are working to promote increases in the scope of formalized syntheses in ecology and evolution but also want to provide discussion, detailed dialog, and personally as an editor, more creativity in review and engagement (Lortie 2013). The rejection rate for these submissions is low and often very, very rapid with some accelerated acceptances within one-week of submission. In the spirit of mindfulness and to further and align the mission of Oikos for these potential contributions, a brief summary of some challenges (or less gently pitfalls) that can be avoided will enhance our successes as a community active in synthesis.

Pitfalls

Summary publications on best practices and approaches to meta-analyses and systematic reviews continue to proliferate for ecologists (Vetter et al. 2013, Gómez-Aparicio and Lortie 2014, Koricheva and Gurevitch 2014, Doerr et al. 2015, Lortie et al. 2015, Shrier 2015) in addition to the recent handbook (Koricheva et al. 2013). The checklist provided by Koricheva and Gurevitch (Table 2, 2014) for plant ecologists absolutely applies to Oikos submissions. Nonetheless, a few trends have emerged in handling meta-analysis submissions and require mention. *Transparency* in reporting is still critical and often largely underdeveloped in the original submission. Repeatability and delineation of selection criteria are significant advantages of formalized synthesis (Moher et al. 2009,

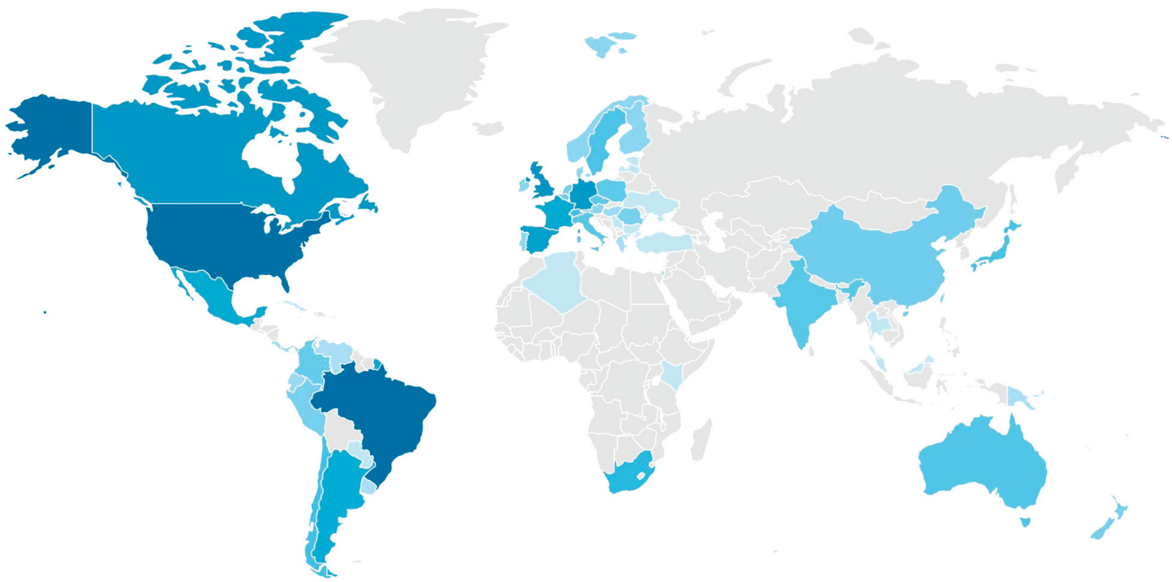

Figure 1. A map of the altmetrics reach of 71 meta-analyses published in the journal Oikos including up to October 2015 (source <www.impactstory.org>). Darker shading indicates higher frequency of discussion beginning with light grey shading.

Higgins and Green 2011, Vetter et al. 2013) and just good open science practices (for instance the work of the Open Science Framework <https://osf.io/tvyxz/wiki/home/>). A PRISMA report (<www.prisma-statement.org>) and appendix listing all studies including those excluded are important resources and facile contributions to this end. Ideally, the descriptive dataset from the synthesis (studies, criteria and key bibliometric elements of each publication) can also be published a priori in an online repository that provides a DOI and cited as a dataset within the manuscript – such as the synthesis of Oikos meta-analyses herein (Lortie 2015). Editors and referees alike have posited sample size challenges in the peer-review process. There is no magic number in the number of studies or independent instances from within a set of studies that examine the processes or hypothesis in review. However, cursory trends indicate that at least 10–15 studies are needed to warrant a synthesis and that independent instances from a set of studies often begin upwards of 30 tests for the submissions to date. A more productive way to frame meta-analytic sample sizes is the definition of the search. The framework of concepts should ensure that a broad enough set of terms capture both the primary purpose of the review and potentially related terms. Sensitivity analyses and checks of more than one bibliometric search tool are also appropriate. Readership likely also best relates to a balance point within the synthesis that mitigates increasing specialization in the sciences (Lortie 2014) by provides sufficient evidence to effectively examine the topic at hand. More is not necessarily better either as a very broad synthesis including close to a 1000 studies or more from queries can produce challenges in assigning appropriate ecological context, defining and identifying subgroups, and scope of implications. The *purpose* of the meta-analysis or systematic should nonetheless be explicit.

Typically, these syntheses explore the strength of evidence for a set of hypotheses and predictions and themselves thus have a purpose and outcomes or questions. Meta-analyses are often successful at this scale of exploration versus primary prediction or hypothesis testing terms. The meta-level can push testing to examination at larger-scales. This does not preclude critical scientific thinking, and the few instances of rejection to date were those that did only summary with limited examination of implications, gaps, or theory development. *Systematic review versus meta-analysis* is an increasingly common inquiry to the editorial staff and in teaching synthesis (<www.slideshare.net/cjlortie/zen-the-art-of-scientific-synthesis>).

Systematic reviews describe the meta-data of a field of research (who, where, why, how) whilst meta-analyses use the data directly (what was found). As stated previously, both are powerful synthesis tools (Lortie 2014), and the decision to report the literature landscape (systematic review) versus mean efficacy of a treatment or outcome across studies (meta-analysis) depends on both the purpose of the study and the reporting in the literature. Appropriate *statistics* have been a limited challenge in submission to Oikos but were effectively resolved with revisions. The rule-of-thumb has been that primary big data, collected identically can sometimes be treated with conventional statistics such as generalized linear models, but data from different studies must be treated with meta-analytics to control for between-study variation. *Creativity* in terms and concepts has been high at Oikos for all submissions and clearly a process of discovery for each sub-discipline. These discoveries can however be more extensively communicated in all these syntheses because they will inform future efforts and illuminate the extent that semantic development is needed for ecologists as a whole.

Precis

Integrated primary data synthesis efforts such as The Long Term Ecological Network, National Ecological Earth Observatory Network, the Nutrient Network, Global Lake

Ecological Network, and many others are engendering an important sense of real place for data synthesis. These distributed, collaborative networks also avoid many of the pitfalls associated with many, smaller idiosyncratic individual studies on a topic such as inflated heterogeneity associated with different protocols versus the causal effects of the treatments or key factors (Ioannidis 2005). Synthesis programs such as Science for Nature and People provide targeted syntheses of existing research and data on nature and people, and DataONE provides a single framework that can embrace multi-scale queries across all environmental science member node repositories for the domain. The collective effects of both sets of initiatives (networks and programs) promote not only direct aggregation activities that generate syntheses including meta-analyses and systematic reviews but indirect benefits including shared terminology, refined semantics, better meta-data, open data, and a shift in the culture of ecological practitioners to embrace larger-scale analyses and knowledge standards. Journals such as Oikos that advance synthesis nonetheless have an important role to play in these positive changes. The capacity to publish and cite datasets is of course critical. However, there is still a need for mindful, quantitative descriptions of complexes of both data and traditional publications. Ideally, meta-analyses in ecology will increasingly use the datasets directly in addition to the papers. Journals can require that datasets be published alongside primary research papers to ensure that the most effective syntheses are viable. This is becoming increasingly common in ecology including at Oikos, but it must be more rigorously enforced. Journals can also provide a recognized outlet for meta-analyses and consider setting *every contribution in this category as open access* for policy makers and the public. Basic ecology has the unique capacity to inform many other disciplines, and at the minimum, we must make the syntheses available to all. Finally, many novel syntheses in the form of meta-analyses and systematic reviews published in journals catalyze a field of research in at least two ways. Both positives are in effect emergent properties of the aggregated datasets. Firstly, identification of research gaps is a very common outcome of a synthesis. Instead of the usual adage at the end of standard contributions that 'more research is needed', syntheses can directly pinpoint the research needed quantitatively and de facto qualitatively. Secondly, some of the best meta-analyses and systematic reviews do the heavy lifting in aligning the terminology, concepts, and hypotheses for an ecological subdiscipine. This is a non-trivial process, and conceptual frameworks provided in the form of a concept map are often akin to an ontology and provide a visual guide to the data and theory associated with a specific set of studies. These are key innovations and a clear example of creative synthesis. In Oikos in particular, we endeavor to promote these practices in togetherness of data, theory and synthesis.

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