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An online database and desktop assessment software to simplify systematic reviews in environmental science

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ABSTRACT

We describe software to facilitate systematic reviews in environmental science. Eco Evidence allows reviewers to draw strong conclusions from a collection of individually-weak studies. It consists of two components. An online database stores and shares the atomized findings of previously-published research. A desktop analysis tool synthesizes this evidence to test cause–effect hypotheses. The software produces a standardized report, maximizing transparency and repeatability. We illustrate evidence extraction and synthesis. Environmental research is hampered by the complexity of natural environments, and difficulty with performing experiments in such systems. Under these constraints, systematic syntheses of the rapidly-expanding literature can advance ecological understanding, inform environmental management, and identify knowledge gaps and priorities for future research. Eco Evidence, and in particular its online re-usable bank of evidence, reduces the workload involved in systematic reviews. This is the first systematic review software for environmental science, and opens the way for increased uptake of this powerful approach.

Software/data availability

Eco Evidence was developed by researchers and programmers at the eWater Cooperative Research Centre, Australia. It was publicly released in December 2012. The Eco Evidence Analyser (v1.1.1) software can be downloaded from www.toolkit.net.au/tools/eco-evidence, and the Eco Evidence Database is also accessible at this address using any web browser. New users must register with the Toolkit website, but there is no charge for registration or subsequent use of Eco Evidence. The Eco Evidence Database has an ASP.NET web interface driven by a Microsoft SQL Server database. Users must go through a self-approval process before they can add new citations and evidence items. The database is highly scalable and was designed to be accessed by multiple concurrent users. All records are associated with the user who enters/edits them, with the latest edit being kept. The relational database schema uses an entity–attribute–value data model to store the evidence information. This allows the structure of an evidence item to be changed without requiring additional software development work. The database schema is highly normalized and only requires the storage of basic data types (i.e. numbers, strings), so the storage requirements are minimal. The Eco Evidence Analyser software was written in C#.NET and runs on Microsoft Windows (requires.NET 4.0 framework). The installer file is 4.15 MB in size. Projects (including the local databases contained therein) are saved in XML format and the standardized report is HTML.

1. Introduction

Environmental studies are often carried out under conditions that make it difficult or impossible to infer with confidence that one thing actually causes another (Beyers, 1998). For many large-scale investigations, treatments cannot be randomly allocated to experimental units, replication (and hence statistical power) is low, and we are faced with the presence of confounding environmental gradients (e.g. variation in rainfall). When investigating environmental impacts, the suspected cause has often occurred years or

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decades earlier, meaning we have no 'before' data against which to compare present-day conditions.

However, demonstrating causality is important, both for advancing our state of ecological understanding and helping to develop theory, and also for using this knowledge in evidence-based management of natural and impacted environments. This latter consideration is especially important in contested decision spaces, where the relative benefits of natural and human uses of environments must be weighed when making management decisions (e.g. Poff et al., 2003). If individual studies cannot make strong inferences about ecological causes and effects, then more evidence is needed from elsewhere (Downes et al., 2002).

Like many scientific disciplines, environmental science has seen a recent explosion in the amount of literature available (e.g. Stewardson and Webb, 2010). It has even been hypothesized that this information deluge has reached the point where it is holding back scientific progress, rather than aiding it (Attwood et al., 2009). Methods and tools are required to help make sense of this mountain of literature. *Systematic reviews* are one way to analyse the knowledge contained within a large body of literature. A systematic review explicitly treats the literature as data (Khan et al., 2003). They commonly employ statistical analyses, and use transparent and repeatable methods to test specific hypotheses across sets of papers. This approach brings a level of discipline and focus to a review far greater than that usually seen in the *narrative* reviews that dominate environmental science. Narrative reviews use written descriptions to summarize a large body of research, but seldom seek to test whether there is or is not enough evidence to support or refute an ecological hypothesis. The short narrative reviews found in the introductions of most journal papers are often poorly executed and do little to argue for the importance of the research that follows (Maier, 2013). Systematic reviews are common in several other scientific disciplines, most notably medical research and patient management (Keene and Pullin, 2011). However, despite calls for their increased use in ecology and environmental science (Pullin et al., 2009; Sutherland et al., 2004), they are not yet widely used. This lack of uptake might be explained by the related observations that systematic reviews can be laborious (CEBC, 2010), and that to date there have been no tools specifically designed to reduce this workload to a manageable level.

Our aim in this paper is to introduce the Eco Evidence software package. To assist new and potential users to learn how to use the software, we provide examples of its use. The software implements the systematic review method developed by Norris et al. (2012), and fully described therein. It is not our purpose here to explain the previously-published method, nor justify its logical basis. However, briefly, the Eco Evidence method has its basis in the epidemiological method of causal criteria analysis. Faced with similar issues of weak inference as those described above, epidemiologists developed causal criteria as a means of building a strong argument for causality from a collection of otherwise individually-weak pieces of evidence (Hill, 1965; Tugwell and Haynes, 2006). In Eco Evidence, the individual pieces of evidence are bivariate associations (e.g. fish diversity associated with flow seasonality; discussed below) that are drawn from the literature. The key aspects of Eco Evidence are: an open-access online database for permanent storage and sharing of the 'evidence items' used in systematic reviews, allowing future re-use of the evidence by the same or other reviewers; an analysis package that guides users through the 8-step method of Norris et al. (2012), thereby providing a standardized approach for synthesizing literature evidence; and the provision of a standard report, which provides complete transparency of the review undertaken.

The Eco Evidence package can facilitate ecological systematic reviews in the same way, for example, that the RevMan package (http://ims.cochrane.org/revman) has aided medical reviews. Moreover, the database component of Eco Evidence is the first such publicly-available evidence database in any discipline that uses systematic reviews. More fundamentally, Eco Evidence has the potential to improve the standard of reviews in environmental science, answering questions across a body of literature and identifying the knowledge gaps that need to be filled by new research (sensu Maier, 2013).

2. The Eco Evidence software

Eco Evidence consists of two components: the online database for storing and sharing evidence items, and a desktop analysis tool to guide users through the Norris et al. (2012) framework to assess the level of support for causal hypotheses. The Eco Evidence Analyser (v1.1.1) software can be downloaded from www.toolkit.net.au/tools/eco-evidence, and the Eco Evidence Database is also accessible at this address using any web browser. New users must register with the Toolkit website, but there is no charge for registration or subsequent use of Eco Evidence.

2.1. Eco Evidence Database (EED)

The Eco Evidence Database (hereafter EED) is an online database for storing and sharing evidence items. It provides a permanent repository for environmental evidence and allows users to access and use evidence items entered by other users. It is accessible via any web browser and requires no installation or system customization.

2.1.1. Data entry

Registered users can add citations and evidence items to the database. Changes made to the database are tagged with the user name as a basic means of quality control. Basic users are able to create and edit only their own contributions, while 'power' users are able to edit all contributions (Webb et al., 2011). When adding a new citation (e.g. journal paper), the database first tests for the presence of duplicates. Once the citation is created, the user can add evidence items to it. Users can also add new evidence items to existing citations. To add evidence, the user must first extract it from the citation, a process explained below. We refer to this user as the 'extractor' for clarity in the following sections.

2.1.2. Data structure

The key data items managed in the EED are citations and evidence items. For each citation, the database contains standard bibliographic information (author, title, source, abstract, keywords). It also contains basic study characteristics (region in which the study took place, climatic classification, ecosystem type, spatial and temporal scale of the study, broad class of study type), which are selected by the extractor from dropdown menus and are used to facilitate searching through large collections of studies. Attached to each citation are one or more evidence items.

The evidence item consists of a set of database fields that collectively describe the hypothesized cause–effect association reported in the citation (Table 1). These fields have been determined through user input, data usage, and discussions with users and collaborators. Only a small subset of the 34 fields is compulsory, but a number (9) are necessary if the evidence item is to be used in a subsequent analysis using the Eco Evidence Analyser tool. Inputs to many of the fields are restricted through the use of control elements (radio buttons, tick boxes, drop-down lists) to ensure consistent data entry. Free-text fields allow the extractor to describe the evidence more fully.

At the core of an evidence item is the basic putative cause–effect association. It consists of a standard term for the cause, a standard