Evidence synthesis for tackling research waste

There is an immediate need for a change in research workflows so that pre-existing knowledge is better used in designing new research. A formal assessment of the accumulated knowledge prior to research approval would reduce the waste of already limited resources caused by asking low priority questions.

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The term 'research waste' is defined as research outcomes with no societal benefits[1]. This occurs when the knowledge generated is either not innovative and novel, when it is not applicable to real-world situations, or when the research effort itself does not have societal impact (for example, training students or engaging stakeholders). Waste can occur at any stage of the research process[2]: question setting; methods; accessibility; and reporting (Table 1). In medicine, research waste is a well-established concept, and in 2009 research waste was estimated to cost US$85 billion[2], with few signs of improvement in the last decade[1]. There is little reason to believe that the situation is substantially different in ecology and conservation, although there are no field-wide formal assessments of research waste.

Emerging topics are beginning to address some of the factors that result in wasted research efforts (Table 1). In particular, there is increased focus on methodological improvements in individual studies (for example, refs. [3,4]), and on open science leading to improved accessibility and reporting[5]. Less formal effort is devoted to the question-setting stage. Here we suggest that 'evidence synthesis' should be considered as an additional stage of research (Table 1, Supplementary Fig. 1) which closes the research process into a loop, leading to additional benefits in terms of reducing research waste at the question-setting stage.

Reducing waste in question setting

There are two related areas where research waste can be reduced by taking into account the existing body of evidence through evidence synthesis methods.

Low priority questions. New studies may ask low priority questions — those that are irrelevant to stakeholders. The remedy to this is to include stakeholders in the research commissioning process[2]. Evidence synthesis, or horizon scanning for novel problems, should be used to provide evidence to practitioners, researchers and

Table 1 | The research process stages, examples of potential research waste and how ecology and conservation can limit these

Research stage	Examples of potential for research waste	Where ecology and conservation can reduce waste
Research question	Irrelevant questions asked.	Co-development of research questions with stakeholders and using appropriate methodology such as Delphi exercises to avoid issues such as group think or not including the right group of experts or stakeholders.
	Previous knowledge not properly taken into account.	Make use of evidence synthesis methods (for example, cumulative meta-analysis, systematic mapping, systematic reviews and meta-analysis) to identify questions that are not satisfactorily answered.
Study design and methods	Poorly designed studies, under-powered (or over-powered and so on).	Use simulations or power analysis prior to undertaking data collection. Predefine effect size of interest with stakeholders (that is, do not rely on rules of thumb for 'statistical significance').
	Using inappropriate statistical tools (including overfitting and so on).	Better training of early-career researchers in methods. Open code and data to ensure reproducibility of methods.
	Questionable research practices[3] that lead to poor quality research.	Open science (open methods and data, reproducible methods, sharing code and so on). Better training of early-career researchers in methods of open science and evidence synthesis.
Reporting	Lack of open data.	Open science (open methods and data, reproducible methods, sharing code and so on).
	Hypothesizing after the results are known.	Pre-registration of hypotheses.
	p-hacking.	Open science (open methods and data, reproducible methods, sharing code and so on).
	File-drawer syndrome (only some studies are published).	Pre-registration of hypotheses and methods. Open publishing (including preprints).
	Incomplete reporting, making evidence synthesis difficult or impossible.	Increasing the knowledge of researchers and peer reviewers on what is essential to report, and changing journal guidelines where necessary to ensure all relevant information is reported.
Accessible full publication	Publications not available to practitioners and decision makers.	Open-access publishing, including making resources available to researchers to be able to publish open access.
Evidence synthesis	Research not designed or presented in the context of the existing knowledge.	Using systematic reviews, systematic maps, meta-analysis and so on to shape research priorities. Where good quality evidence is available these should be synthesized, providing evidence to relevant stakeholders. Research gaps should be the focus of primary studies.

Research process stages adapted from ref. [2]. Systematic reviews, systematic maps, meta-analysis as well as open-science principles can help in the reduction of waste in all stages of the research process.

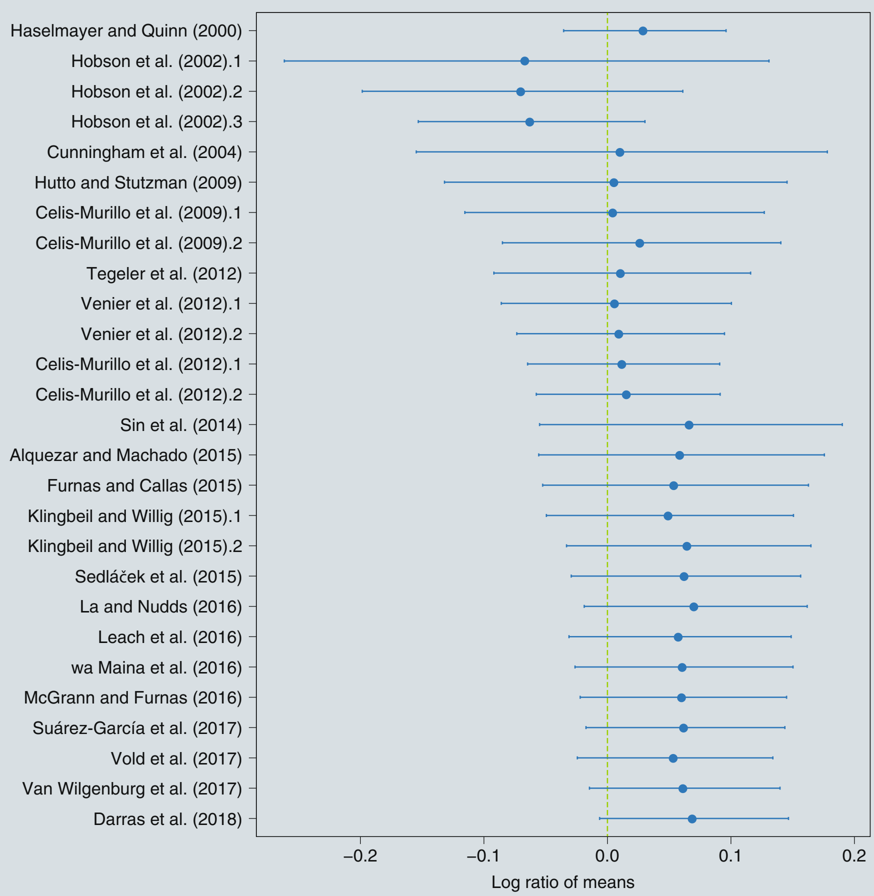
Box 1 | Using cumulative meta-analysis to make research decisions

Imagine you, as a researcher or research funder, want to assess the potential for acoustic recorders to replace human observers for estimating bird abundance. Do we need another research study to determine this? Here we outline an example decision process which would serve to reduce research waste.

Is there previous knowledge available on this topic? Technological advances over the last two decades have allowed this potential to be explored fully, and well over 150 field studies have sought to answer this question. A meta-analysis in 2018[15] explored the pooled effect of these studies using a meta-analytic approach to estimate species richness of birds. Twenty-eight primary studies published between 2000 and 2017 were included in the meta-analysis. Based on the combined evidence from the included studies, they concluded that when human observers (using point counts) and sound recorders sample areas of equal size, there is no difference between estimates of bird species richness. When properly conducted (see specific advice in ref. [15]), it can be inferred that sound recorders can be used to monitor aspects of biodiversity as efficiently as human observers.

Do we need another study to quantify the effect? We adapted the analysis of ref. [15] to demonstrate the use of cumulative meta-analysis (see Supplementary Methods). For the 14 studies conducted since 2014, the effect size (that is, the magnitude of the difference between intervention and control) of studies was consistently close to 0.07 (a difference of around one species; Box 1 Figure). This means that there was no clear difference between acoustic recorders and human observers on bird point counts. It would be wasteful to fund yet another study that addressed this specific question.

What next? If you were interested in acoustic sampling as a means to sample bird species richness, you could proceed with confidence that using acoustic sampling is as effective as human observers in the field. If you are interested in acoustic sampling specifically, you could look for substantial anomalies or heterogeneity between studies in the meta-analysis and design a study trying to understand these differences.



Cumulative forest plot of a meta-analysis on the difference between human observers and acoustic recorders in terms of species richness. The green line indicates the line of zero effect, the blue dots indicate the cumulative effect size with 95% confidence intervals. Studies are ordered by publication year with the earliest studies at the top and the latest studies at the bottom. Full details of each study can be found in Supplementary References; data are based on the meta-analysis of ref. [15].

other stakeholders so that they can identify research gaps that are important to them and to develop future questions[6].

The answer is already known with certainty. If a topic has been sufficiently addressed in the existing literature, we might already know the outcome with high certainty. Further studies that fail to leverage this existing knowledge are at risk of wasting research resources. There are a variety of tools available for research funders and researchers to assess the state of knowledge on the topic of interest. For example, systematic maps (also known as evidence gap maps or evidence maps) were designed to give an overview of the available evidence on a broad topic[7]. They can highlight where there is enough available evidence for a systematic review or where primary research is required due to a lack of evidence. However, users of systematic maps should be aware that the number of papers available on a topic does not equate to the strength of evidence, which should be formally examined before making conclusions about the adequacy of evidence[8]. Systematic reviews can be used to synthesize knowledge about a narrow topic such as the evidence for the effectiveness of an intervention and can provide a statistical summary of the pooled effect size. The statistical combination of numerical data extracted from the evidence base during the process of a systematic review is known as meta-analysis. Meta-analysis is increasingly used in conservation and ecology[5], providing an understanding of the magnitude of the known effect of an intervention across individual studies. These results can be used to identify what new research can add to the current evidence base. Although evidence synthesis can be time consuming (open-source tools for predicting the time investment are available, for example, https://github.com/mjwestgate/PredicTER), the investment in time will facilitate less wasteful research.

Identifying research waste with cumulative meta-analysis

In medicine, one additional tool used to quantify research waste is cumulative meta-analysis. A cumulative meta-analysis typically describes the accumulation of evidence (for example, about the effectiveness of an intervention) across time, and available estimates are added to the analysis in chronological order[9]. Using cumulative meta-analysis, one can identify if there is sufficient evidence to be confident that a reported effect is true. Cumulative meta-analyses demonstrate how new research frequently generates research waste, even when effect sizes are temporally stable and precise[9]. Researchers in domains relying on heterogeneous observational studies (such as ecologists) should beware of temporal instability of effects[10], which should be considered as part of the strength of the existing evidence base. We demonstrate how the approach can be integrated into conservation and applied ecology workflows, see Box 1. Cumulative meta-analysis has already been used in our field to assess time-lag bias[11] but is not commonly used in the way we show here.

Caveats. There are several important caveats that need to be addressed. The heterogeneity in reporting and the drive for novelty in publications means that meta-analysis is currently challenging in applied ecology. There might not be sufficient good quality research to quantify the cumulative effect of even some apparently well-studied phenomena. Power analysis can be used to determine if there is enough primary literature to determine stability of a cumulative effect. Researchers are best placed to add to the evidence base by ensuring that they use comparable measures of outcomes rather than novel ones.

In addition, publication bias, where the direction of statistical significance of the outcome influences the decision to publish the result, might bias the evidence base available. This is a major caveat for all evidence synthesis approaches, but one which can be identified. Funnel plots can be used to identify the potential for non-publication of results (that is, those of small effect size). With cumulative meta-analysis, one can explore publication bias[11] by accumulating the effect sizes in order of journal impact factor, for example. Although this method makes it possible to detect publication bias it will not solve the underlying problem, and researchers should endeavour to reduce publication bias by following open-science principles (Table 1).

Without deliberate research programs of sequential research focused on specific questions in ecology, as proposed in ref. [12], we need to find ways of synthesizing diverse information sources. Methodologists propose use of systems models to combine empirical evidence from systematic reviews and meta-analysis with expert opinion, which allows key areas of uncertainty in a topic to be identified and prioritized for research focus (for example, ref. [13]). Formal value of information analysis can then be undertaken if a decision-theoretic framework exists.

Outlook

Research waste can be reduced and it is the responsibility of research funders, research institutions as well as individual researchers to do so. Researchers and funders could search for existing research syntheses in the literature and on synthesis platforms (for example, https://www.conservationevidence.com/). We agree with the statement targeted at medicine 25 years ago that “We need better research, and research done for the right reasons”[14]. Without a change in focus, ecology and conservation funding will continue to be wasted, which will be detrimental to our efforts to provide solutions to global societal challenges. ❒

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Competing interests

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Additional information

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