The role of reporting standards in producing robust literature reviews

Literature reviews can help to inform decision-making, yet they may be subject to fatal bias if not conducted rigorously as 'systematic reviews'. Reporting standards help authors to provide sufficient methodological detail to allow verification and replication, clarifying when key steps, such as critical appraisal, have been omitted.

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The production of scientific research is growing exponentially[1] and rigorous synthesis of this ever-increasing evidence is becoming an urgent necessity for many researchers and decision-makers, both in policy and practice. A literature review is a textual summary of a topic designed to bring together individual concepts, theories or studies in a digestible overview while generating something new. This is the act of synthesis. Reviews are as diverse as they are numerous, ranging from narrative primers of broad issues to quantitative syntheses using meta-analysis of focused research topics (see Supplementary Table 1)[2]. This difference is driven by the nature of the review authors' aims, the intended users, the requisite level of rigour and comprehensiveness, and the resources available. In primer-style reviews the aim is to provide a novel, digestible summary of a topic, while other types of review synthesize to improve precision, reduce bias in estimation, increase comprehensiveness, raise transparency and accountability or generalize findings across a broad range of contexts. The choice of methods used to identify, screen, appraise and synthesize studies and their findings has a critical impact on the reliability of the review produced[3].

Literature reviews aim to technically synthesize a body of evidence by assembling a set of research studies, extracting each study's findings and combining them to produce or test a hypothesis, theory or conceptual model. These reviews are research items in their own right and, as with all research, should employ a suite of methods to ensure the conclusions obtained reflect the evidence and are not unduly affected by external factors that might introduce bias. Reviewers commonly use meta-analysis; a powerful tool for combining individual effect sizes and measures of variability to generate a more precise estimate of the effect or effectiveness of an impact or intervention[4]. Other methods, such as qualitative synthesis[5], perform a similar role with qualitative research data. Whichever method is used, a review may be susceptible to a suite of biases and limitations if not conducted in a comprehensive, repeatable and systematic way (Table 1). One of these limitations relates to a lack of transparency: if reviews are not reported in a transparent manner it becomes impossible to verify how rigorously they were conducted, whether they may have missed important evidence, or may reflect vested interests, for example. A lack of transparent reporting of methods also reduces the reliability and usability of a synthesis[6]. This is particularly problematic if reviews are used to support decision-making in policy and practice.

Systematic review (and the related systematic mapping; see Supplementary Table 1, points 7 and 8) is a formalized method for synthesizing evidence in a reliable manner that aims to maximize transparency, comprehensiveness and objectivity[7]. Systematic reviews were developed in the field of medicine to deal with rapidly expanding bodies of evidence, the need to make use of existing research in informing clinical decisions and a requirement for rigorous and transparent evidence synthesis[8]. Systematic reviews consist of strict methodological steps that can be broadly separated into the following: (1) developing a protocol; (2) searching across multiple sources of evidence; (3) screening evidence for relevance; (4) retrieving articles; (5) critically appraising study validity; (6) extracting data; (7) performing synthesis of qualitative and/or quantitative data; and (8) documenting all activities in a detailed report[3]. Systematic reviews (and systematic maps[9]) involve steps to mitigate the biases and limitations listed in Table 1. Most importantly, perhaps, they aim to be as transparent as possible by documenting all activities during the conduct of the review. Systematic reviews may be updated periodically[10,11], and transparency allows the methods to be reproduced in an efficient way.

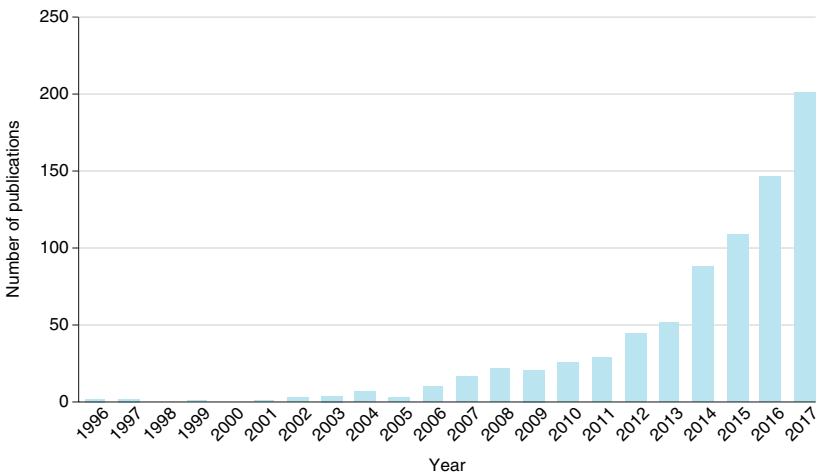

Fig. 1 | Increasing interest in systematic reviews over recent years. The number of publications returned from a search of the Web of Science Core Collections for 'systematic review' in topic words within the 'Environmental science' subject category on 14 April 2018 is shown, divided into annual bins.

Table 1 | A summary of the major limitations and biases that can affect a literature review across each stage of the review process

Review stage	Type of limitation/bias	Description	Possible mitigation measures
All stages	Lack of transparency	The methods used in the review are not reported in sufficient detail to allow replication or verification	Report all activities (including search terms/strings, languages and databases searched, screening process and test for consistency screening, number of included/excluded studies at each stage of the review process and so on) in detail in the Methods section and Supplementary Information
Protocol	Subject drift/question creep	The topic/scope or definitions of the review shift over the course of the review, for example driven by what reviewers find interesting in the evidence base	An a priori protocol sets out the planned methods for the review in detail and is published (and preferably peer-reviewed by subject and methodology experts) prior to commencing the review
Searching (general)	Selection bias/Cherry-picking	Studies included in the review are selected based on awareness of the reviewer	Systematic search across a suite of resources rather than selection of studies with which authors are already familiar
	Lack of comprehensiveness	The evidence base identified is incomplete and may not be representative	Comprehensive searching across multiple bibliographic databases and sources of grey literature, searches in multiple relevant languages
	Media attention bias	Reviewers may be influenced in their selection of articles based on what is discussed in the media	Systematic search across a suite of resources rather than selection of studies with which authors are already familiar with
Searching academic literature	Place of publication bias	Journals with a higher 'impact' and visibility are more likely to publish significant, positive/affirmative research	Comprehensive searching across multiple bibliographic databases
	Citation bias	Some studies, such as those with significant results, are more likely to be cited than others, resulting in a possible bias if citations are used as a basis for article selection	Searching using a variety of different methods, including bibliographic databases, screening bibliographies and citation tracking (forwards or backwards)
	Database bias	Bibliograhic databases select which journals to index and may omit certain bodies of evidence	Comprehensive searching across multiple bibliographic databases
Searching grey literature	Publication bias	Significant and/or positive results may be more likely to be published in traditional academic journals	Comprehensive searching across multiple resources
	Language bias	Two-fold: (1) non-English research may be less likely to be translated and published in 'mainstream' English journals; and (2) searches not performed in non-English languages may miss research published in other language journals	Searching for and inclusion of non-English language evidence
Eligibility screening	Lack of consistency	Different reviewers make different decisions regarding eligibility	Set out planned methods in detail in an a priori protocol developed through scoping of the literature. Test for consistency formally, discussing disagreements and revising criteria where necessary
Retrieval	Dissemination bias	Lack of accessibility (due to limitations of the reviewers' subscription, for example) meaning that some studies are omitted from the review	Comprehensive retrieval of studies
Data extraction	Lack of consistency	Different reviewers extract different data	Set out planned methods in detail in an a priori protocol developed through scoping of the literature. Test for consistency formally, discussing disagreements and revising criteria where necessary
Critical appraisal	Outcome reporting bias	Some study measured outcomes are omitted from a research article despite having been recorded by the authors, possibly due to a lack of significance	Critical appraisal
	Full publication bias	Researchers may only publish parts of their study, for example due to significance	Critical appraisal/author contact

Continued

Table 1 | A summary of the major limitations and biases that can affect a literature review across each stage of the review process (Continued)

Review stage	Type of limitation/bias	Description	Possible mitigation measures
	Multiple publication bias	Studies with significant results are more likely to be published across multiple articles	Critical appraisal
	Funding bias	Research funded by those with vested interests may be more likely to show a positive finding	Critical appraisal
	Lack of consistency	Different reviewers make different conclusions regarding study validity	Set out planned methods in detail in an a priori protocol developed through scoping of the literature. Test for consistency formally, discussing disagreements and revising criteria where necessary
Synthesis	Vote-counting	Studies are tallied up according to the direction or significance of their results, with the number of studies used as a weighting of the evidence in favour of or refuting a hypothesis	Conduct critical appraisal to classify studies according to their validity. Weight studies when conducting synthesis to give greater influence to more valid evidence. Account for the magnitude of effect and not just the direction/significance when synthesising results across studies. Perform sensitivity analysis to examine the influence of validity on review findings
Synthesis and reporting	Discussion bias/interpretation bias	Reviewers focus on different portions of the evidence base when discussing their findings, possibly due to their specific research background or interests	Draft the discussion as a team through consensus. Do not focus unduly on single studies unless their validity warrants examination over the broader evidence base. Focus on patterns and consistency in the evidence base rather than individual findings. Use appropriate synthesis tools, such as meta-analysis, to identify patterns
Update	Time lag bias	Studies with significant results are more likely to be published sooner than non-significant results	Update searches immediately before completing the review to include research published since searches were originally conducted. Regularly update the systematic review at a frequency dependent on the publication rate in the evidence base. Examine the presence of time lags between study conduct and publication in relation to different patterns in the evidence base (in terms of the types of studies and their findings)

Since their adaptation from the field of healthcare to environmental management and conservation[7], interest in systematic reviews has increased substantially (Fig. 1). Across healthcare, social policy and environmental management there currently exist three major bodies that coordinate systematic review activities (Cochrane, the Campbell Collaboration and the Collaboration for Environmental Evidence (CEE)). These organizations aim to support the conduct and publication of systematic reviews by developing guidance, setting and enforcing standards, and publishing systematic review protocols and reviews in dedicated libraries (such as the CEE journal *Environmental Evidence*; www.environmentalevidencejournal.org). These organizations ensure that reviews published through their platforms reach a required minimum standard of quality in conduct and transparent reporting. The increasing interest in systematic reviews as a gold standard method for synthesizing evidence has meant that an increasing number of reviews are published outside of these coordinating organizations. Without a dedicated system for quality control and peer-reviewing complex systematic review reports, many of these reviews do not reach the minimum standards stipulated by coordinating bodies and are subject to many of the biases and limitations mentioned above[12]. In one assessment[13], 93% of reviews on the effectiveness of marine protected areas were found to be of low or intermediate reliability. Most commonly, reviews lack sufficient transparency to be truly classed as systematic.

Reporting standards for various types of studies, including reviews, exist across all research disciplines (the EQUATOR Network (www.equator-network.org), for example). They share a common aim of increasing the quality and quantity of information documenting the conduct and results of scientific research. Reporting standards are now widely used in primary healthcare research and have also been established for systematic reviews. In the field of healthcare, a presubmission checklist (PRISMA; preferred reporting items for systematic reviews and meta-analyses) was produced almost 10 years ago for systematic reviews and meta-analyses[14]. This checklist aims to increase transparency in evidence syntheses by prompting review authors to ensure important methodological details are reported in their papers. Since its production, PRISMA had been cited almost 25,000 times by mid-2017[15] and is 'endorsed' by at least 5 editorial organizations and 179 journals[16].

Although it represents a substantial advancement towards improving the standard of reporting in systematic reviews, PRISMA is not without its limitations[17]. PRISMA is not easily adaptable to systematic reviews from other disciplines and the types of evidence and synthesis they involve. In the field of environmental science, it is often not possible to conduct quantitative synthesis (via meta-analysis, for example) on all evidence found in a systematic review: many studies do not release the associated data[18]. In these instances, a narrative synthesis may be the only valuable means of summarizing studies. Additionally, novel methods for the synthesis of qualitative or mixed-methods data are emerging and are particularly beneficial for building theories and frameworks[19]. Systematic mapping (see Supplementary Table 1) is an emerging method for summarizing the nature of the

evidence base, identifying where areas with little or no evidence (knowledge gaps) and substantial evidence (knowledge clusters) are to be found[9].

To provide guidelines and standards for transparently documenting syntheses of environmental evidence, ROSES has been produced (Reporting standards forsystematic evidence syntheses; www.roses-reporting.com)[17]. ROSES is an initiative specifically adapted to environmental evidence and the syntheses needed to summarize it. It is based on the CEE Guidelines and Standards for Evidence Synthesis in Environmental Management[3]. ROSES forms are checklists adapted to protocols or review reports for systematic reviews and systematic maps, and they are accompanied by a flow diagram for transparent reporting of the review process (including numbers of articles included and excluded at each stage of the review conducted). The ROSES forms can support review authors when conducting and reporting their activities and act as a presubmission checklist to ensure that all necessary information has been included. Furthermore, ROSES forms include requirements to report key metadata (descriptive information) that describe the review's methods (for example, review question elements, details of the search string, number of search records included at each stage of the review). Together, the checklist and metadata provide a brief overview of the review's methods, and facilitate peer-review and editorial decisions.

As the interest in systematic review and mapping as the gold standard in summarizing evidence grows, mainstream academic journals will see an increasing number of subpar systematic reviews[12] that suffer from varying degrees of bias and other limitations. Reporting standards, such as ROSES, can facilitate authors in providing sufficient methodological detail to allow verification and replication of methods, making it apparent when key methodological steps, such as critical appraisal, have not been performed adequately. Such reporting standards may also help to raise awareness of formal systematic review guidance and support, may support review conduct and facilitate editorial decisions and peer-review. By embracing reporting standards, researchers and editors across environmental science can make a strong commitment to increasing the reliability of evidence synthesis and supporting better evidence-informed environmental policy. ❐

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Additional information

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Obstacles facing Africa's young climate scientists

Current and future climate change poses a substantial threat to the African continent. Young scientists are needed to advance Earth systems science on the continent, but they face significant challenges.

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Future climate projections suggest that Africa is one of the most vulnerable continents to extreme climate events/disasters[1,2]. Climate change and environmental degradation pose a substantial threat to Africa[3], but also provide an opportunity for the continent to develop local knowledge and skills, and to thrive in the long term. Strengthened investment in the study of Earth system sciences and a conscious effort to nurture scientific talents are needed to position the continent for a favourable future. However, early-career scientists in Africa face numerous challenges in securing resources, training and research positions. These challenges threaten to undermine the continent's ability to deal with environmental change resulting from climate change.

Inadequate facilities

Earth systems science is a new field in most African universities and faces many hurdles. One such challenge is underfunded and inadequate research facilities[4]. Computational and e-infrastructure limitations are especially salient; high demand for supercomputers and sufficient storage for big data far exceed what most African universities can afford. The ratio between the number of usable computers and users is low in most universities[5]. Some also struggle to bear the cost of subscribing to closed-access journals. While open-access journals provide unmeasurable succour to researchers in these institutions, scientists are left with an incomplete view of progress in their fields.

Underfunded research

Federal governments, civil society and the private sector are the main sources of funding for Earth systems science, but the annual budgets for most African countries show very low to no funds allocated to scientific research[6]. This is a sombre