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Training future generations to deliver evidence-based conservation and ecosystem management

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Ecological Solutions and Evidence
BRITISH ECOLOGICAL SOCIETY

REVIEW

Training future generations to deliver evidence-based conservation and ecosystem management

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Abstract

1. To be effective, the next generation of conservation practitioners and managers need to be critical thinkers with a deep understanding of how to make evidence-based decisions and of the value of evidence synthesis.
2. If, as educators, we do not make these priorities a core part of what we teach, we are failing to prepare our students to make an effective contribution to conservation practice.
3. To help overcome this problem we have created open access online teaching materials in multiple languages that are stored in Applied Ecology Resources. So far, 117 educators from 23 countries have acknowledged the importance of this and are already teaching or about to teach skills in appraising or using evidence in conservation decision-making. This includes 145 undergraduate, postgraduate or professional development courses.
4. We call for wider teaching of the tools and skills that facilitate evidence-based conservation and also suggest that providing online teaching materials in multiple languages could be beneficial for improving global understanding of other subject areas.

KEYWORDS
critical thinking, education, evidence, open access

Making informed conservation and ecosystem management choices is based upon a sound understanding of the relevant evidence. There is an increasing wealth of conservation science available, and access to this is becoming easier. But, are conservation practitioners being trained to utilize this information?

In conservation, decision-making is often based upon past experience or expert knowledge, as opposed to the full body of scientific literature (e.g., Pullin, Knight, Stone, & Charman, 2004; Rafidimanantsoa, Poudyal, Ramamonjisoa, & Jones, 2018). The failure to include scientific evidence in decision-making has the potential to reduce the effectiveness of management, or even lead to detrimental actions being undertaken (Walsh, Dicks, & Sutherland, 2015). Evidence-based conservation (EBC) seeks to avoid this by providing tools to facilitate and inform decision-making. To do this, scientific evidence is collated and critically appraised for its quality and relevance, and integrated with other knowledge, experience, values and costs (Sutherland, Pullin, Dolman, & Knight, 2004). Wider adoption of EBC requires conservation professionals to be trained in its principles and taught how to use it to inform conservation decision-making.

1 | EVIDENCE USE IN CONSERVATION MANAGEMENT

Although there is increasing availability and accessibility of scientific literature, uptake of evidence use within conservation has been slow. For example, despite evidence published 8 years ago showing that bat bridges are ineffective in reducing bat collisions with vehicles (Berthinussen & Altrigham, 2012), they continue to be put up around the United Kingdom at a considerable cost: in 2020, Norfolk Council spent £1 million installing them along a new road. The collating of scientific research (through evidence synthesis) has revealed numerous concerns about the effectiveness of widely used conservation practices and ecosystem management actions. Reviews of agri-environment schemes highlight that some actions are more effective in achieving objectives than other commonly used alternatives (Dicks et al., 2014). A number of simple and routine practices, such as installing bumblebee nest boxes (Lye 2009) are insufficiently effective at increasing pollination to justify use. Cleaning birds after oil spills has been shown to be ineffective in increasing survival of oiled birds and their offspring, yet is also routinely undertaken at a substantial cost (Williams et al., 2012). Many practices may even be detrimental, such as in the case of moving leopards away from dense human populations to reduce conflict, instead *increased* the number of attacks (Athreya, Odden, Linnel, & Karanth, 2010). Furthermore, critical analysis and understanding of details and context is crucial for interpreting the relevance of available evidence. For example, the effectiveness of wildflower strips at promoting pollinators varies depending on their implementation, management, landscape context and how they are designed (Haaland, Naisbit, & Bersier, 2011). The outcome of most well-studied conservation actions depends on context in this way. As a result of these findings, there have been numerous calls to incorporate evidence more effectively into conservation and management of biological resources (Legge, 2015; Sutherland & Wordley, 2017; Sutherland et al., 2004).

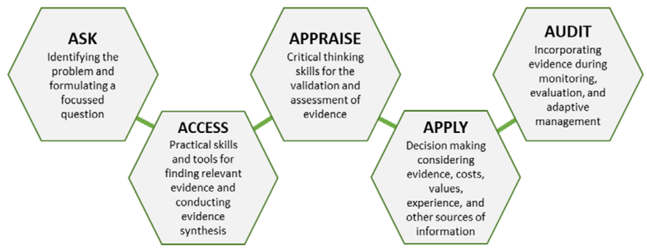

FIGURE 1 The core skills of evidence-based conservation. Based on Young et al. (2014)

However, there are several long-standing barriers to evidence use in conservation and environmental management decisions (Arlettaz et al., 2010; Habel et al., 2013, Walsh, Dicks, Raymond, & Sutherland, 2019; Sunderland, Sunderland-Groves, Shanley, & Campbell, 2009). These include: barriers to accessing the evidence, with much of it behind paywalls or not being presented in a user-friendly format; decision-makers not having the time or skills to read and interpret all of the relevant scientific literature; and uncertainty or conflicting results causing confusion and hampering understanding (Walsh et al., 2019). Many of these barriers are being addressed through collation and synthesis of evidence in various formats: *Conservation Evidence* (conservationevidence.com), *Collaboration of Environmental Evidence* (http://www.environmentalevidence.org/), *Applied Ecology Resources*, and the new journals *Ecological Solutions and Evidence* and *Conservation Science and Practice*. These initiatives save time by compiling all of the evidence in one place, avoid jargon by summarizing information in plain language summaries, and increase accessibility through open access and providing abstracts in languages other than English (Schwartz et al., 2019).

Despite these advancements, one barrier associated with a lack of training in key skills in appraising and using evidence still requires attention. Practitioners have reported to have limited or no scientific education or training, and often have little access to professional development and continuous education courses. They have also reported that the general skills required in research use and EBC are limited: the ability to search, read, interpret and critically appraise scientific literature is often lacking (Walsh et al., 2019).

Biological conservation is delivered by a wide range of organizations in the public, private and not-for-profit sectors. Thus, promoting behaviour change across these dispersed and diverse organizations poses particular challenges when compared to industries characterized by fewer, larger players, such as healthcare. Providing entrants to these conservation organizations with the skills to find, interpret and evaluate evidence can help to address these inconsistencies and lead to wider adoption and change.

An obvious starting point to address these education and training gaps would be at the institutions that train conservation practitioners, namely universities and other higher education organizations, as well as professional development courses typically offered by learned societies (e.g., British Ecological Society, Society for Conservation Biology).

TABLE 1 Summary of the extent to which the application of evidence-based conservation (EBC) is incorporated into key conservation science textbooks published since 2000. We have focused on textbooks that might be used for introductory or advanced courses in conservation science and that are not specific to one domain (e.g., conservation genetics, conservation behaviour)

Textbook	Extent to which EBC concepts are covered	Acknowledgement of EBC and its role in conservation	Examples or application of EBC in practice	Information on the mechanics of EBC (i.e., how to do it)	Provision of references to EBC resources
The Conservation Handbook (Sutherland, 2000)	First published description of evidence-based conservation	Describes how evidence-based medicine worked and how could be applied to conservation	Outlines how it could be applied	Describes possible process	None
Quantitative Methods for Conservation Biology (Ferson and Burgman, 2002)	Uses word evidence several times to demonstrate the data available to support certain hypotheses. Book is about using quantitative methods to solve conservation problems, so implicitly suggests the need for science in decisions. No mention of evidence-based decisions, though the field was only just emerging	None	None	None	None
Conservation Biology (Pullin, 2002)	Extensive coverage of EBC in Chapter 15 - Putting the science into practice	Yes – fully defined and described	Several examples provided	Not in sufficient depth to enable training	Yes – key references from that time period included
Experimental Approaches to Conservation Biology (Bartol and Gordon, 2004)	None despite several chapters that cover policy aspects and prioritizing science when making decisions	None	None	None	None
Practical Conservation Biology (Lindenmayer and Burgman, 2005)	No content on EBC	None	None	None	None
Conservation Biology: Foundations, Concepts, Applications, 2nd Edition (Van Dyke, 2008)	No content on EBC.	None	None	None	None
Conservation Biology for All (Sodhi and Ehrlich, 2010)	Discusses some principles of evidence use but no explicit coverage	None	None	None	Single reference to the collaboration for environmental evidence
A Primer of Conservation Biology, 5th Edition (Primack, 2012)	No content on EBC	None	None	None	None
Conservation, 2nd Edition (Hambler and Canney, 2013)	No content on EBC	None	None	None	None
Wildlife Ecology, Conservation and Management (Sinclair, Caughley and Fryxell, 2014)	The word evidence is used extensively within the text (and there is a brief section on the nature of evidence) but there is no discussion of what EBC is	None	None	None	None

(Continues)

TABLE 1 (Continued)

Textbook	Extent to which EBC concepts are covered	Acknowledgement of EBC and its role in conservation	Examples or application of EBC in practice	Information on the mechanics of EBC (i.e., how to do it)	Provision of references to EBC resources
Essentials of Conservation Biology, 6th Edition (Primack, 2014)	No content on EBC	None	None	None	None
Conservation Science: Balancing the Needs of People and Nature, 2nd Edition (Kareiva and Marvier, 2015)	Extensive coverage of EBC in Chapter 12 – Adaptive Management and Evidence-Based Conservation	Yes – fully defined and described	Several examples provided	Not in sufficient depth to enable training	Yes
An Introduction to Conservation Biology, 2nd Edition (Sher and Primack, 2019)	No content on EBC	None	None	None	Section with links to key resources and organization in conservation including several relevant to EBC
Conservation Biology (Cardinale, Primack, and Murdoch, 2019)	No content on EBC	None	None	None	None

Tools and learning materials need to be developed in order to overcome the barriers that have made evidence-based decision-making challenging. If decision-makers (including practitioners) are trained to critically evaluate and use evidence from an early career stage, then as they attain leadership positions in which they can influence organizational policy or action, they could drive how conservation is performed in the future (Cook, Mascia, Schwartz, Possingham, & Fuller, 2013). Here we discuss in more detail how EBC skills, including synthesis and use of evidence, is currently taught in conservation, and describe a set of open access materials that we have produced to aid further teaching of this subject. It is hoped that this paper can inspire and empower instructors to incorporate aspects of EBC into their various courses and training programs, as a way to improve conservation decisions in the future.

2 | TEACHING EVIDENCE-BASED PRACTICE AND CRITICAL THINKING

Studies have shown that despite a large body of evidence examining how to best teach critical thinking in educational settings (reviewed in Behar-Horenstein & Niu, 2011) the education system (e.g., colleges, universities, professional development courses) can fail to provide learners with the tools and guidance they need to think critically (Bailin, 2002; Pithers & Soden 2000; Smith 2020; Tiruneh, Verburgh, & Elen, 2014). This can leave individuals struggling to properly interpret, understand, and evaluate evidence. In some cases where political parties and the media purposely or inadvertently mislead, people actively distrust evidence. Making decisions without critical-thinking skills can lead to poor choices (Bouygues, 2018). Furthermore, teaching young people to think critically enables them to make better judgements about decisions, risks, and opportunities (Abrami et al., 2015). Whilst the use of evidence is routine in many teaching environments, the explicit teaching of how to synthesize, critically evaluate and use evidence is inconsistent.

The theory and application of evidence-based practice has been a key feature in medical and healthcare education and professional development training for decades (Glasziou, Del Mar, & Salisbury, 2003, Straus, Glasziou, Richardson, & Haynes, 2018, with the first edition in 1997). There have also been renewed requests to improve the curricula and create standards of teaching for evidence-based medicine skills (Dawes et al., 2005; Glasziou, Burts, & Gilbert, 2008). As a result, healthcare practitioners are skilled in interpreting and using relevant evidence in their day-to-day decisions and across broader healthcare provision and policy. For example, the Centre for Evidence-Based Medicine, University of Oxford, and the British Medical Journal, have online resources for medical students and teachers: https://www.cebm.net/ebm-library/ and https://bestpractice.bmj.com/info/toolkit/. Several health-focused systematic reviews found that the most effective methods of teaching skills of evidence-based practice involved multi-faceted, practical methods such as lectures, workshops, journal clubs and real clinical settings that were linked to assessment (Young, Rohwer, Volmink, & Clarke, 2014). We envisage, within a decade, conservation students will be just as savvy to the concepts and skills of evidence-based practice for environmental decisions, but to achieve this will need the support, guidance, and leadership of educators.

TABLE 2 Open access materials provided in the Applied Ecology Resources platform to teach evidence-based conservation

Lecture title	Content	Level	Associated exercises
An introduction to evidence-based conservation for researchers	- What is scientific evidence and why is it important? - How is scientific evidence used in conservation? - What are the barriers to scientific evidence use in conservation? - How are these barriers being addressed? - Evidence synthesis - Challenges of evidence synthesis	All. Content can be tailored to any level of study	Exercise on searching and critically evaluating literature for a chosen taxa/habitat and their threats
An introduction to evidence-based conservation for decision-makers	- Complex nature of environmental decisions - What is scientific evidence and why is it important? - How is scientific evidence used in conservation? - What are the barriers to scientific evidence use in conservation? - How are these barriers being addressed? - Evidence synthesis to support management decisions - Other solutions to using scientific evidence in decisions	All. Content can be tailored to any level of study. With an emphasis on the practicalities of including evidence in management decisions, this introduction lecture may be more appropriate for professional development or land management focussed courses or modules	Some exercises throughout the lecture Link to a decision-making tool to help go through the stages of making an evidence-based decision
Planning and designing experiments to improve conservation practice	Why is testing of management actions important? Why is not more testing done? How to plan and design an experiment in the real world: What is the specific question you want to answer? What data is needed to answer this question? How can these data be collected? Is it practical to collect these data? Will your question be answered? Is it worth collecting these data? Reporting results and reducing publication bias	All. Content can be tailored for any level of study	Tasks throughout the lecture and accompanying hand out with tasks and an exercise on designing an experiment
Systematic reviews and meta-analysis	Why do we need research synthesis? Research synthesis types Systematic reviews: Question formulation, Literature search, Literature filtering, Data extraction, Data synthesis, Management recommendations and research gap identification Meta-analysis: Formulate a question, Search for relevant studies, Standardize the results of each study (effect size) into a 'common currency', Weight the effect size by the sample size, Average effect size across all studies and test if this average effect size differs significantly from zero, Look for publication biases and heterogeneity	Advanced – for those who want a more in-depth understanding of systematic reviews and meta-analysis	An exercise on conducting meta-analysis from a real data set
Using the Conservation Evidence database	What is the Conservation Evidence project? How can the Conservation Evidence database be used?	All. Content can be tailored for any level of study	The presentation has tasks spread throughout and a follow-up exercise on using CE to create a management plan

3 | EVIDENCE-BASED CONSERVATION IN TEXTBOOKS

Textbooks are commonly used for undergraduate and even graduate courses in conservation science (Hudson, 2009, Primack, 2003; Stinner, 1995). They provide an important role (for better or worse) in educating the next generation of conservation practitioners and decision-makers. In some cases they are assigned as the formal 'class text' where the instructor works through the text from start to finish. In other cases, one or more texts are suggested as resources for students, or instructors consult various texts when framing their courses. As such, what appears in textbooks have a huge role in determining the educational content. An examination of key conservation science textbooks published since 2000 (i.e., when the concept of EBC was developed) revealed very few examples of where the principles of EBC had been defined and introduced as a specific topic or where examples of relevant resources were provided (Table 1). Moreover, not a single textbook provided direction on the approaches and tools used in EBC to underpin the application of science into policy and practice. This may not be a surprise, as key papers on EBC were not published until as recently as 2004 (e.g., Sutherland et al., 2004). However, it is remarkable that our targeted search failed to locate meaningful inclusion of the term 'evidence-based conservation' in almost all contemporary conservation science textbooks. Our search has been limited to those texts that are conservation-specific and we acknowledge that there may be some texts outside of this search that refer to EBC (e.g., 'Living in the Environment' by Miller and Spoolman).

3.1 | Teaching and learning resources

To aid teaching the subject 'evidence-based conservation', we have provided a range of materials for use and modification, available at Applied Ecology Resources (https://www.britishecologicalsociety.org/applied-ecology-resources/about-aer/additional-resources/evidence-in-conservation-teaching/). These materials cover the core themes of teaching the principles and practice of EBC (Figure 1), as well as more in-depth materials on subjects such as meta-analysis and designing management interventions as experiments (Table 2). The material comprises lectures, lecture handouts, workshop suggestions, assessments, a library of weblinks, exercises and a reading list. These are available in a number of languages. This material is free of copyright (material donated by authors) and material can be used in their current form, modified, or combined with the lecturer's own material.

A range of existing courses (Appendix 1) currently have at least one lecture or workshop devoted to the topic of EBC. This includes 60 undergraduate, 73 graduate and 12 professional development courses across a wide range of environmental and biological sciences. The authors of this piece all run such a session (but are not necessarily course organizers). We hope this widespread teaching of EBC will raise the awareness that many conservation textbooks fail to adequately cover this topic. Having more core texts devoting chapters to this topic could aid teachers and students alike.

Initially, EBC could be added as a single lecture in a course, but over time, entire courses could be developed to equip practitioners and researchers with the skills to implement EBC decision-making and lead the change within their future professional roles.

Over time we expect the use of collated evidence to become a standard element of all conservation training and included in standard textbooks and online courses. Whilst these resources are aimed specifically for conservation and environmental management education and training, we believe evidence-based decision-making is a crucial skill for students of any sector.

4 | CONCLUSION

Students attending conservation lectures, tutorials, and professional development courses today will be making the decisions about how best to protect and conserve nature in the future. Providing these learners with the skills necessary to make decisions based on an appraisal of all of the available information, and to think critically about what works and what does not, is vital for ensuring effective conservation. In addition, it is important that they have the confidence and information to break precedent. This includes being able to abandon the *status quo* even if there is significant institutional resistance to change, and to make informed decisions when evidence is imperfect. With this understanding, practitioners and decision-makers will be in a position to demand more and better evidence, using their positions to help direct funding and research efforts to build the evidence base.

The large number and variety of courses globally that have committed to including at least one lecture about EBC within the next year shows the great demand for these skills to be taught. While provision of educational resources is only part of the solution towards wider uptake of evidence-based decision-making, we hope that the collation and sharing of these materials begins to address this demand. We suggest that this could usefully be replicated on a wider scale for other subject areas where there appear to be similar gaps in teaching (e.g., foresight science in conservation). We also make a plea to those writing new conservation textbooks to include material on EBC.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

HD and WJS conceived the idea. HD, TA, MC, CNC, SJC, NRH, JPGJ, NL, JCW and WJS led the writing of the manuscript and associated materials. All authors contributed to the drafts and gave final approval for publication.

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No data was used in this study.

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Additional supporting information may be found online in the Supporting Information section at the end of the article.

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