An evidence-based evaluation of systematic conservation planning

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Abstract

Systematic conservation planning is a discipline focused on applying spatial ecological data to help advise those faced with value-laden conservation decision-making. It holds the potential to ensure the most important areas of land and sea are retained for biodiversity and ecosystem services, whilst simultaneously helping to avoid conflict with human uses. In this thesis my aim was to outline the factors which influence the effectiveness of systematic conservation planning in terms of achieving biodiversity conservation outcomes alongside broader social and financial objectives. I began by developing a conceptual framing of impact and evaluation methods in relation to systematic conservation planning. Following this I catalogued the literature on systematic conservation planning from across 29 academic and non-academic sources, using a gold standard evidence synthesis method, systematic mapping. This involved screening over 10,000 articles, from which three constituted high-quality impact evaluations, and a further 43 discussed the outcomes of plans but lacked appropriate study designs. To improve the efficiency of conducting large evidence syntheses like this, I reviewed 22 specialist software packages used across multiple disciplines. Finally, I chose a case study approach to understand barriers to evaluation and perspectives of effectiveness amongst a range of elite interviewees responsible for systematic conservation planning exercises in Australia in the 1990s and 2000s. This thesis highlights a shortfall in efforts to monitor and report on the outcomes of systematic conservation planning interventions. One reason is the inherent challenge of interpreting impact when counterfactual analyses are difficult to conduct, but my results also suggest insufficient academic focus on implementation and evaluation in this discipline. The three high-quality impact evaluations and Australian case studies provide valuable examples of how to overcome barriers to evaluation and point to the range of factors which influence interpretations of effectiveness. Conservation academics are ideally positioned to assist in the design and conduct of rigorous evaluations and evidence synthesis activities going forwards.

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This thesis is dedicated to Claudia Comberti, who continues to inspire so many.

Statement of authorship

I confirm that the thesis I am submitting is primarily my own work. Specific contributions by co-authors are laid out below and letters from each co-author are provided in Appendix 6.2.

Emma J McIntosh, September 2018

Introduction EJM's sole work.

Paper 1 McIntosh EJ, Pressey RL, Lloyd S, Smith RJ, Grenyer R. 2017. The impact of systematic conservation planning. Annual Review of Environment and Resources 42:677–97.

EJM led analyses and led drafting of the manuscript, RLP, SL, RJS and RG contributed conceptual ideas and contributed to the writing of the text. All authors read and approved the final manuscript.

Paper 2 McIntosh EJ, McKinnon MC, Pressey RL, Grenyer R. 2016. What is the extent and distribution of evidence on conservation outcomes of systematic conservation planning around the globe? A systematic map protocol. Environmental Evidence 5:e1–13.

EJM conceived the idea of a map in 2014 and subsequently discovered an independent conception of the idea by MCM and RJP (Bottrill & Pressey 2009). EJM led and drafted this manuscript. EJM, MCM and RG co-authored the manuscript. RLP provided input on terminology and inclusion/exclusion criteria. All authors read and approved the final manuscript.

Paper 3 Kohl C*, McIntosh EJ*, Unger S*, Haddaway N, Kecke S, Schiemann J, Wilhelm R. 2018. Online tools supporting the conduct and reporting of systematic reviews and systematic maps: a case study on CADIMA and review of existing tools. Environmental Evidence 7:e1-17. *Co-first authors

CK drafted the CADIMA part of the manuscript, EJM performed the review of software tools and drafted the associated parts of the manuscript, SU was responsible for the programming of CADIMA and all authors contributed to the final manuscript. All authors read and approved the final manuscript.

Paper 4 McIntosh EJ, Chapman S, Kearney SG, Williams B, Althor G, Thorn JPR, Pressey RL, McKinnon MC, Grenyer R. 2018. Absence of evidence for the conservation outcomes of systematic conservation planning around the globe: A systematic map. Environmental Evidence 7:e1-23.

This study was led by EJM. The research question was originally conceived by MCM and RLP, who advised throughout the project. Title screening was conducted by EJM and SC, abstract screening by EJM, SC, SGK, BW, GA and JPRT, and full-text screening by EJM, SC and SGK. Full-text coding was conducted by EJM and BW. RG advised on the design and execution of the study. All authors read and approved the final manuscript.

Paper 5 McIntosh, E.J. n.d. Barriers to the evaluation of systematic conservation plans: Insights from landmark Australian plans. Biological Conservation (submitted).

EJM designed and led this study, collected and analysed the data and drafted the manuscript.

Discussion EJM's sole work.

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Introduction

"Planning is all about coming to agreement on a vision for the future and then making it happen. But how do you know when you've arrived at that vision - and what if it's not what you hoped? The Monitoring and Reporting System is like a GPS, it tells you how you are travelling on the journey, whether you've arrived and even shows you some of the roads less travelled that would reward exploration on the way."

– Tim O'Loughlin (quoted in Parks and Wildlife Service 2013 p. iv)

Background and thesis rationale

Conservation of the earth's remaining biodiversity is one of humanity's greatest challenges (Barnosky et al. 2011). When mismanaged, human demands for space and natural resources endanger other species and entire landscapes (Malhi 2017). Conservation planning can be used to allocate resources and actions efficiently, particularly given that funds for biodiversity conservation are rarely sufficient (Waldron et al. 2013; Groves & Game 2016a). Each investment in conservation action comes at the expense of other projects which cannot be funded, so trade-offs are inevitable (Bottrill et al. 2008). This requires transparent and rigorous approaches to determine the most practical conservation priorities for decision makers (Adams et al. 2018).

Systematic conservation planning (SCP) is a discipline which has evolved to address these demands (Margules & Pressey 2000). It has been used to support decision making around conservation investments such as prioritising actions for threatened species (Joseph et al. 2009), undertaking spatial planning to advise on biodiversity offsetting (Brownlie et al. 2005; Pouzols et al. 2012) and to design or rezone protected area networks (Fernandes et al. 2005; Kremen et al. 2008; Jumin et al. 2018).

Despite their wide use, SCP approaches are resource intensive (requiring specialist planning skills, large datasets and extensive consultations), often take years to develop, and can cost millions of dollars even before implementation (Bottrill & Pressey 2012). The required data collection efforts can lead to the stalling of much needed conservation actions (Grantham et al. 2008; Maxwell et al. 2014), and they may not be an efficient approach for creating protected area networks where resources are limited and conservation intervention is urgently required (Naidoo et al. 2006; Knight et al. 2011c). Furthermore, in a discipline focused on the

optimisation of conservation decision making, a concerning knowledge gap exists around the effectiveness of SCP approaches themselves.

Not knowing where, when and how SCP is most effective can lead to a lack of buy-in from key stakeholders; plans not being implemented and a misdirection of conservation funds; all of which can undermine support for other conservation efforts in a region. In contrast, conservation planners who are armed with information about what works can target research gathering exercises (Maxwell et al. 2014), better manage stakeholder expectations (Rodríguez-Rodríguez et al. 2015) and maximise the likelihood of conservation decision making resulting in the persistence of species and functioning ecosystems (Adams et al. 2018).

To shed light on the effectiveness of SCP interventions, I reviewed evaluation frameworks applicable to planning, conducted a systematic mapping exercise to synthesise available published evidence, and explored case studies to understand aspects of effectiveness unlikely to be provided in written reports or publications. As this thesis evolved, an important focus became impact evaluation of complex conservation interventions, and innovation in evidence synthesis methods.

On a personal level, I was motivated to undertake this research to better equip myself to return to working as an applied conservation scientist. My understanding of SCP was that it is specifically intended for implementation (Margules & Pressey 2000; Kukkala & Moilanen 2013), and to bridge the divide between theoretical research and on ground conservation actions (Knight et al. 2006a; Cook et al. 2013). Given that SCP presents a highly regarded approach for minimising environmental damage, I was interested to learn how it has been most effectively applied and what I could learn from those examples. I was also intrigued by the degree to which decision support tools, like Marxan (Ball & Possingham 2000), improve the transparency of consultation exercises and conservation decision making (Carwardine et al.

2008; Knight et al. 2011b). Finally, I was curious to explore a wider range of perspectives on the role of SCP in practice, beyond those of the scientists involved.

Research aims and objectives

The original aim of this thesis was to outline the factors which influence the effectiveness of SCP exercises. I had hoped to explore correlates of success in different contexts by undertaking a meta-analysis of implemented plans and their outcomes. Instead I identified a significant evidence gap which prevented comparisons between plans. As a result, I modified my central aim to the following:

To explore the effectiveness of SCP exercises including how effectiveness is perceived, measured and reported. This was broken into four secondary aims:

Aim 1: Formulate a conceptual approach to defining and measuring conservation impact in relation to SCP and determine what type of evidence is required to evaluate planning processes.

Aim 2: Characterise the extent and distribution of evidence on conservation outcomes of SCP around the globe.

Aim 3: Assess existing tools and approaches for increasing the efficiency of evidence synthesis activities.

Aim 4: Explore barriers to evaluation through examination of landmark case studies in SCP.

Literature overview

In this section I outline the key topics addressed in this thesis: systematic conservation planning and approaches to evidence synthesis. Detailed literature reviews are provided within each paper, particularly alongside the development of a conceptual framework in Paper 1.

Systematic conservation planning

Systematic conservation plans have been developed worldwide (proxies indicate numbers range from hundreds to thousands) (Figure I.1). The majority of interest in SCP to date has been from academics and planners in North America, Oceania and Europe, reflecting those regions with greatest capacity to undertake data driven conservation planning exercises.

The field of SCP has been selected for analysis in this study because it specifically incorporates the core biological principles of adequacy, complementarity, comprehensiveness, irreplaceability, representativeness, threat and vulnerability, alongside non-biological considerations, such as effectiveness, efficiency, flexibility and replacement cost, and social and political feasibility (for more on these principles, see Paper 1) (Naidoo et al. 2006; Guerrero et al. 2010; Eklund et al. 2011; Ban et al. 2013; Mills et al. 2013). No other technique for selecting priority areas for biodiversity conservation allows for consideration of as broad a range of inputs and SCP is widely considered to be the most influential paradigm for conservation planning (Margules & Pressey 2000; Knight et al. 2006b; Pressey & Bottrill 2009).

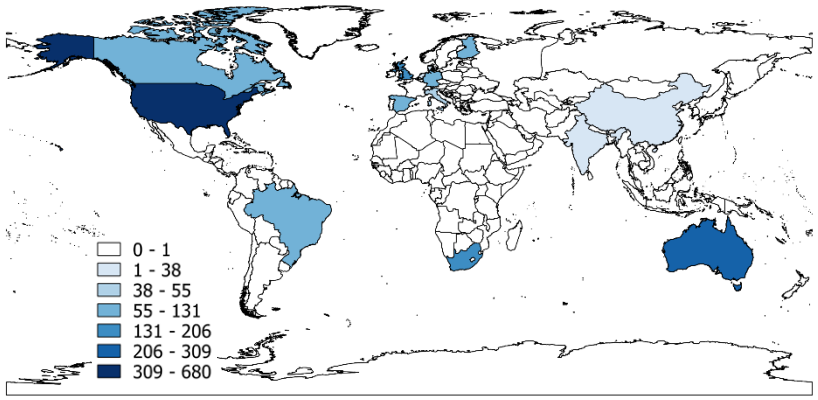
(Overleaf) Figure I.1: Proxies of the number and distribution of systematic conservation planning (SCP) activities globally. a) The most popular software used in SCP, Marxan, was downloaded by 6,708 users from 4,701 organisations in 184 countries between 2011 to 2016 (Watts 2018); b) Number of marine spatial prioritisations (an analytical exercise conducted during the broader SCP process) led by organisations from different countries and number of studies undertaken per marine ecoregion (MEOW), reproduced from Álvarez-Romero et al. (2018)*, c) location of self-reported SCP planning interventions, based on a survey of conservation practitioners (Sinclair et al. 2018), and d) academic publications relating to SCP published between 1980 and 2011 by country of author (created from data in Fig 2 (Kukkala & Moilanen 2013)).*

a

b

c

d



A relatively low proportion of studies in the SCP literature focus on implementation and evaluation of plans (Mair et al. 2018). Of those literature reviews which have been attempted, most only focus on a plan's scientific foundation (e.g. data inputs, choice of biodiversity surrogates and model algorithms (Kukkala & Moilanen 2013)), rather than on biodiversity responses or socio-political markers of a plan's long term effectiveness e.g. ongoing local support of a resultant protected area (Knight et al. 2010; Ban et al. 2013; Raymond & Knight 2013). An earlier attempt to develop an evaluation framework for conservation plans resulted in an outcomes framework arranged according to five types of capital: natural, social, human, financial and institutional (Bottrill & Pressey 2012; Bottrill et al. 2012). This framing has helped to focus attention on the breadth of potential outcomes of conservation plans beyond the intended ecological outcomes and formed the basis of evaluation frameworks and reporting used in this thesis.

Evidence synthesis

Calls for more rigorous evaluations of conservation effectiveness (Ferraro & Pattanayak 2006; Cook & Hockings 2011; Miteva et al. 2012; Groves & Game 2016b) have led to growing awareness amongst conservation scientists of the evidence-based approaches used to define and measure effectiveness in other crisis disciplines, such as the Cochrane Collaboration in public health, the Campbell Collaboration in social welfare and 3ie in international development. The Collaboration for Environmental Evidence (CEE) is playing a similar role in the environmental sciences, firstly, by functioning as an open partnership between scientists, managers and practitioners and secondly, by developing protocols and maintaining a centralised repository of protocols, systematic maps and reviews (Haddaway & Pullin 2014).

Evidence synthesis is the process of collating, assessing and summarising the best available evidence for a particular intervention, usually to provide recommendations for policy and practice (Pullin & Knight 2013). Approaches to evidence synthesis vary depending on the

intended audience, purpose, degree of uncertainty expected and level of rigour required and can range from expert elicitation through to multi criteria analyses (Pullin et al. 2016). A hierarchy of sorts exists with literature-based evidence synthesis activities, where time, cost, breadth and the degree of rigour and critique of included studies increases from traditional literature reviews (often not possible to reproduce) through to systematic reviews, where every relevant study is expected to be included and careful documentation promotes repeatability (Collins et al. 2014) (Figure I.2).

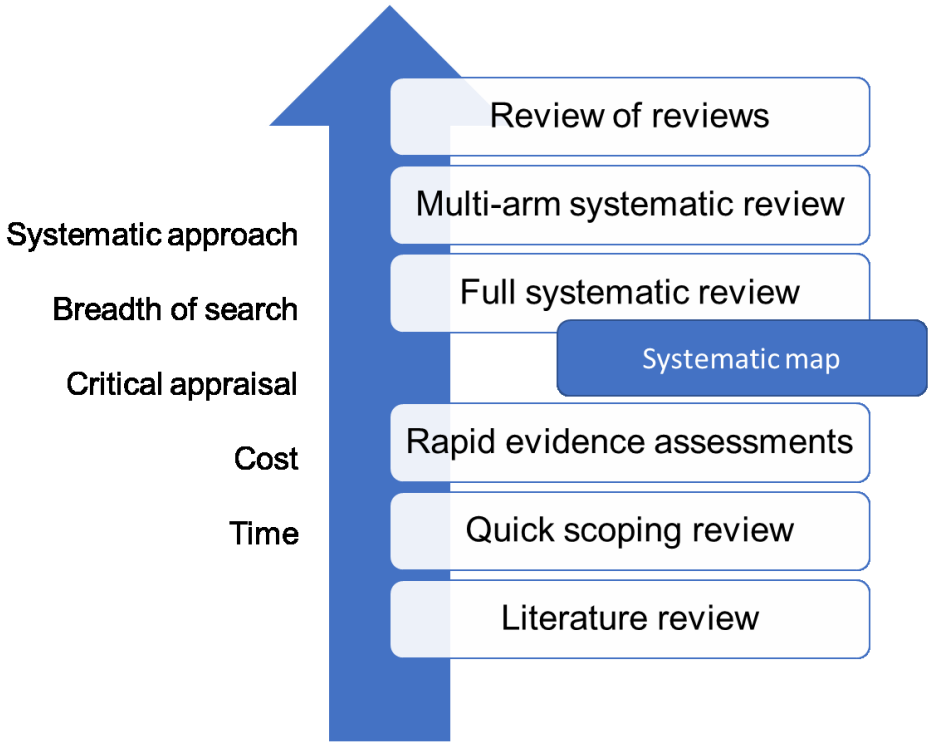


Figure I.2: Representation of a hierarchy of evidence synthesis methods (adapted from Collins et al. 2014). A systematic map is often a precursor to a systematic review or can be a stand-alone exercise following mostly similar methods.

One approach on this hierarchy is systematic mapping, the collation, description and cataloguing of available evidence on an intervention or topic of interest e.g. 'what evidence exists for the effects of intervention X' (Haddaway et al. 2015b; James et al. 2016). A systematic review question is necessarily more targeted than a systematic map, in order to arrive at a recommendation of best practice e.g. 'how much of X intervention does it take to

increase Y outcome by Z amount'. The methods overlap, although systematic reviews additionally involve critical appraisals of available evidence and methodical and objective assessments of a particular research question (Pullin & Knight 2009).

To date, rigorous evidence syntheses have not been used to assess the effectiveness of SCP interventions and systematic mapping offered the potential to identify any previously overlooked evaluations of SCP. Papers 2 and 4 in this thesis also represent the first application of the CEE methods to a complex planning intervention, where a combination of actions can result in a multitude of intended and unintended outcomes at different stages of implementation.

Overview of methods

This thesis involved a focus on: developing a conceptual framework for assessing the impacts of SCP, evaluation methods, approaches to evidence synthesis, and case study research. The justification for these and related methods is provided below, and further details are provided within each thesis paper.

Conceptual framing

Before commencing any analyses, it was necessary to formulate a conceptual framing of impact evaluation in the context of systematic conservation planning. This was conducted as a research exercise to operationalise the rest of the thesis and was published in Paper 1. I determined what would constitute outputs and outcomes at various stages of planning, and how these compare with demonstrable impacts. I explored how other planning disciplines have approached evaluation of similar process-based interventions and developed a reporting framework with the categories of information which would assist evaluators of plans (which was also used in Paper 4).

Systematic mapping

In the absence of a definitive repository of systematic conservation plans from which to draw trends and extract lessons, a comprehensive review of the literature was required. Rather than conduct a standard literature review limited to a subset of academic journals like several earlier reviews (Knight et al. 2008; Kukkala & Moilanen 2013; Kullberg & Moilanen 2014), I chose to undertake a full systematic mapping exercise following best practice guidelines developed for the environmental sciences by the Collaboration for Environmental Evidence (CEE 2018) (Table I.1). This approach has the advantage of involving a broader range of sources, which is highly relevant in a discipline where practitioners are unlikely to publish in the academic literature (Haddaway & Bayliss 2015). These methods also emphasise repeatability and transparency about any search limitations, and results are made open access in a centralised repository to encourage shared learning. Additional considerations included that a systematic map complemented concurrent research efforts to catalogue conservation plans through surveys of conservation practitioners (Sinclair et al. 2018) and a database of academic publications on marine spatial prioritisations (Álvarez-Romero et al. 2018). It also built on the foundation for a systematic review laid by Madeleine McKinnon (nee Bottrill) (Bottrill & Pressey 2009; Bottrill 2011).

Systematic mapping is becoming more common in the environmental sciences but methods still lag behind other disciplines in terms of innovations used to screen and synthesise large bodies of literature (Thomas 2013). I attempted to improve on existing methods wherever possible, including using web scraping tools to extract Google Scholar records and organisational reports outside of standard databases (Haddaway et al. 2015a). My interest in approaches from disciplines outside the environmental sector led to a review of software designed to support systematic maps and reviews (Paper 3) and co-authorship of a publication about emerging technological approaches to evidence synthesis (Westgate et al. 2018). I also

explored the possibility of using machine learning approaches to speed up the abstract screening process (O'Mara-Eves et al. 2015; Rathbone et al. 2015b). A pilot exercise suggested that the tools and methods to do this are not sufficiently robust or user tested for my purposes but increased interest and uptake (e.g. Cheng et al. 2018) suggests they soon will be.

Table I.1: Differences between systematic maps and systematic reviews (reproduced from James et al. (2016)).

Stage in 'evidence synthesis'	Systematic map	Systematic review
Objective	Describes the state of knowledge for a question or topic	Aims to answer questions with a quantitative or qualitative answer
Question formulation	Question can be open-framed or closed-framed. Topic can be broad or narrow	Question is usually closed-framed
Search strategy	No limitation on research evidence that can be included (e.g. primary and secondary research)	Evidence is limited to primary qualitative or quantitative research. For example, comparative, prevalence or occurrence type studies
Article screening	Articles not obtainable at full text (where the full document is not available) or studies with limited data may be included	Article full text is usually required to extract relevant data
Data extraction	Information describing the study and its methods are extracted. Study results may not be extracted	Information describing the study and its methods and studies' qualitative or quantitative results extracted
Critical appraisal	Critical appraisal optional	All included studies critically appraised for study internal and external validity
Synthesis	Trends in the literature, knowledge gaps and clusters identified but no 'synthesis of study results' carried out	Qualitative or quantitative synthesis of study results where possible using appropriate methodology (e.g. meta-analysis). Knowledge gaps identified
Report	Describes and catalogues available evidence relating to a topic of interest, identifying knowledge gaps and knowledge clusters. Implications for policy, practice and research made	Narrative and qualitative or quantitative synthesis study results (e.g. meta-analysis) to answer the question (where feasible). Implications for policy and practice, and identification of knowledge gaps for future research

Qualitative interview analysis

To complement the breadth of a systematic map, case studies were undertaken to add depth and provide opportunities for exploring hypotheses about the way in which planning is implemented and how effectiveness is perceived (Flyvbjerg 2006). These were the Great Barrier Reef rezoning and the North East New South Wales forest agreements in Australia, which are considered test cases of systematic conservation planning. My choice of two Australian case studies reflected the fact that Australia is the birthplace of SCP (Kirkpatrick 1983; Pressey 2002), and these Australian plans have now been implemented long enough to expect ecological outcomes to be clearly observable. Familiarity with context and culture is also extremely important when trying to access elite interviewees (Beamer 2002) and when interpreting the relative influence of contextual factors and cultures, so my Australian nationality was also a factor in case study selection.

I interviewed a wide range of senior stakeholders involved in each planning case study, in the knowledge that natural resource planning can affect, and be shaped by, many sectors and influences. In doing so I focused on achieving 'convergent validity', an overlap in terms of concepts, but where different sources of variation are introduced beyond the construct of interest (Beamer, 2002). Most retrospective reports of conservation interventions present the views of scientists and planners only and do not compare perspectives (Fernandes et al. 2005; Osmond et al. 2010; Weeks et al. 2014). The fact that a central ‘success’ narrative is told about the Great Barrier Reef rezoning time and time again, despite a compensation blow-out twenty times the initial budget (Macintosh et al. 2010), particularly caught my attention when selecting case studies and designing the interview strategy.

Thesis structure

This thesis consists of five first-authored articles submitted to international academic journals, four of which have been published to date.

- **Paper 1** introduces the discipline of systematic conservation planning and explores the suitability of different impact evaluation frameworks and monitoring approaches to the discipline;
- **Paper 2** outlines the protocol for a systematic mapping exercise to thoroughly assess the existing literature on evaluations of systematic conservation planning;
- **Paper 3** presents an analysis of existing tools designed to assist with managing the conduct of systematic maps and reviews, and introduces a tool specifically designed for the environmental sciences;
- **Paper 4** directly links to Paper 2 and presents a completed systematic map and assessment of over 10,000 articles, and highlights an important evidence gap in the published literature on impact evaluations;
- **Paper 5** involves the use of high-profile case studies in Australia to explore barriers to evaluation of SCP exercises and, in the absence of evaluations, perceptions of effectiveness based on the reflections of senior decision makers.
- A **discussion** and overall conclusion are provided to draw together key findings and outline future directions for this research.

Articles adhere to the standard length and style of each journal but have been reformatted for consistency and a central reference list has been compiled.

1

Paper 1: The impact of systematic conservation planning

The published article is available online:

McIntosh EJ, Pressey RL, Lloyd S*, Smith RJ, Grenyer R. 2017. The impact of systematic conservation planning. Annual Review of Environment and Resources 42:677–97. Doi: 10.1146/annurev-environ-102016-060902

*This text reflects the accepted manuscript but may not include minor editorial changes made prior to publication. *Samuel Lloyd now goes by Samuel P Sinclair*

Abstract

Systematic conservation planning (SCP) is a rapidly advancing discipline aimed at providing decision-support for choices between alternate conservation actions. SCP is often used to inform choices about areas to protect, in order to optimise outcomes for biodiversity whilst minimising societal costs. Despite the widespread application of SCP approaches, there is limited understanding of the types of impacts resulting from related projects, and when and where it is most effective. This is compounded by the absence of a standardised approach to evaluating and reporting on the outcomes of SCP projects. We highlight the challenges of undertaking evaluations of complex planning processes, the current state of knowledge about the outcomes of SCP projects, and emerging opportunities to improve evaluation. There is a need for clarity around theories of change, definitions of SCP and impact, and for standardised reporting and information-sharing across the discipline.

Keywords

systematic conservation planning; biodiversity conservation; spatial prioritisation; protected area; conservation impact evaluation; reserve design

Acronyms and definitions

(in **bold** at first mention in the manuscript)

Complementarity: accounting for the composition of species assemblages across sites.

Counterfactual outcome: the outcome expected to arise without the intervention.

Effective: maximises total conservation gains.

Goal: broad qualitative statements about the values and beliefs upon which conservation efforts are based.

Grey literature: material not published in academic journals.

Impact: the difference between the outcome of an intervention and the counterfactual outcome arising from no intervention or a different intervention.

Impact evaluation: identifying the intended and unintended consequences of an intervention.

Intervention: action taken to improve biodiversity conservation outcomes.

Objective: quantitative interpretation of broader conservation goals for each spatial feature (e.g. 1,000 ha of a particular vegetation type).

Outcome: the assumed short- and medium-term effects of an intervention's outputs.

Output: measurable product of an intervention.

Persistence: the long-term survival of a species or other elements of biodiversity

Representation: the extent to which a set of reserves samples the full biodiversity of a region.

Spatial conservation prioritisation: the spatial analysis of quantitative data, to identify locations for potential conservation actions.

Systematic conservation planning (SCP): a process for choosing between, locating and implementing conservation actions.

Systematic map: a form of structured database following a standardised search and data extraction methodology (James et al. 2016).

Introduction

Determining how best to allocate scarce resources between several policy or management options is extremely challenging, because of high uncertainty in the face of incomplete information, the need to engage with multiple stakeholders, and the likelihood of conflicting values and objectives. Such decision-making is perhaps most commonly associated with conflict situations, social policy and medical triage (Bottrill et al. 2008), yet it is essential for conservation biology, given the protection of vulnerable species and ecosystems often conflicts with expanding human needs (Soulé 1985).

Systematic Conservation Planning (SCP) is a discipline focused on providing decision-support around the allocation of resources for biodiversity conservation (Margules & Pressey 2000). Among the best known applications of SCP are the rezoning of the Great Barrier Reef Marine Park (Fernandes et al. 2005) (Figure 1.1) and a series of conservation plans in South Africa (Knight et al. 2006a; Pressey et al. 2013). SCP has strongly influenced the conservation planning policies of large conservation organisations like the World Wildlife Fund (Morrison et al. 2009) and The Nature Conservancy (Kareiva et al. 2014), as well as national and regional governments (Fernandes et al. 2005; Osmond et al. 2010; Driver et al. 2012). The ecological principles and specific objectives underpinning SCP mean that it is regarded as one of the most rigorous and defensible paradigms for conservation planning today (Sarkar et al. 2006; Pressey & Bottrill 2009; Watson et al. 2011).

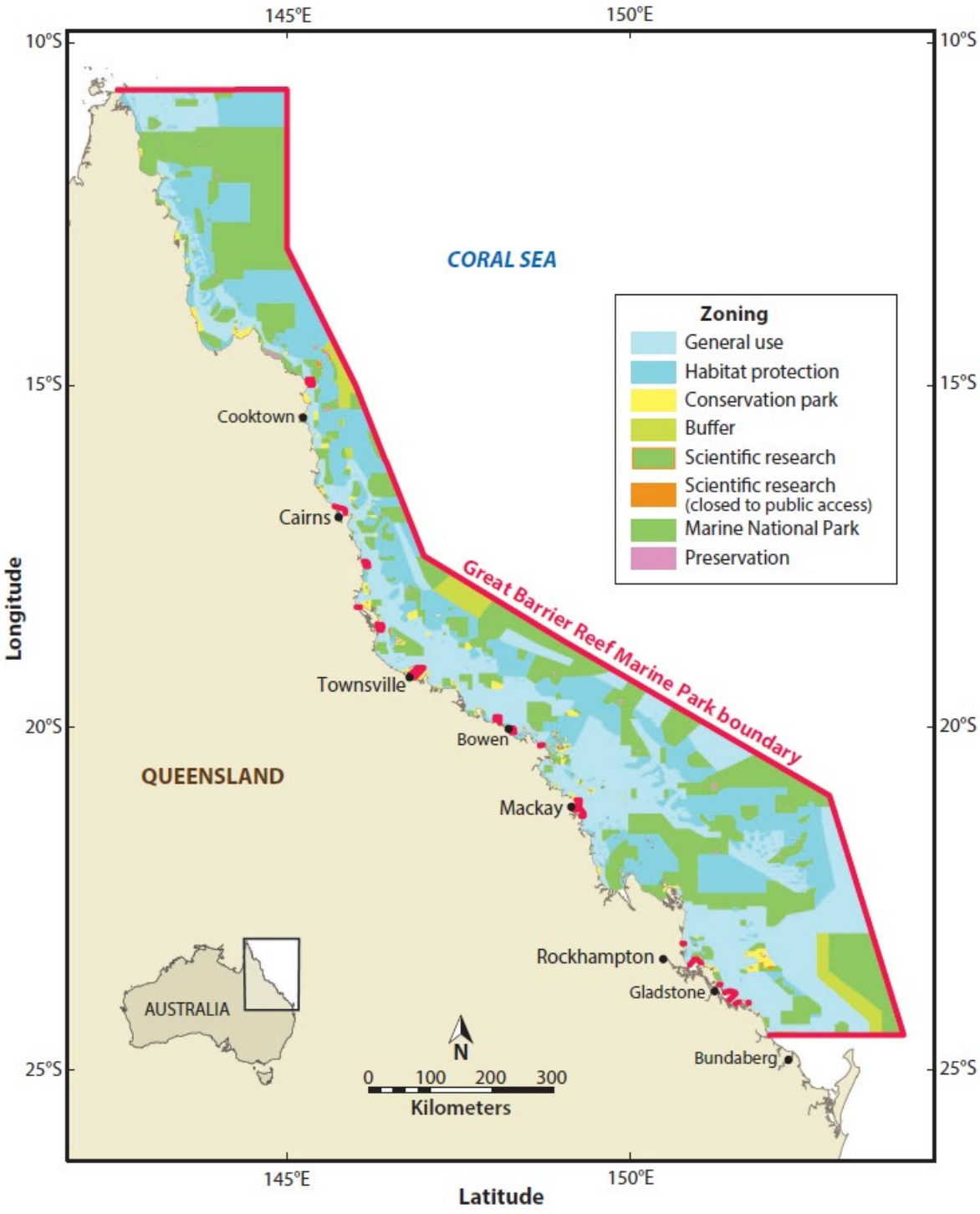


Figure 1.1: Great Barrier Reef (GBR) Marine Park Zoning resulting from the 2003 Zoning Plan, one of the best-known examples of SCP on a large scale. The Representative Area Program (Day 2016) was led by the GBR Marine Park Authority over several years and involved the collection of large biophysical and social datasets across the 344, 400 km2 region, as well as extensive stakeholder consultation (Fernandes et al. 2005; Day 2016). The final plan, enacted by the Australian Parliament in 2004, increased the total area of no-take marine reserves (referred to as Marine National Park or "green zones") from 4.6% to 33.3% of the total marine park, meeting important objectives that included at least

20% protection for each of 70 bioregions (Fernandes et al. 2005). The application of specific, quantifiable objectives during planning is widely acknowledged as having provided a structured process for intense political and social negotiations around changes to commercial and recreational fishing zones (E.J. McIntosh, unpublished interview data). This map shows only the zones within the GBR Marine Park; it does not show the coral reefs or any other components of the GBR ecosystem (for details of the zones, see http://www.gbrmpa.gov.au). Note: Map Projection: Unprojected Geographic Horizontal Datum: Geocentric Datum of Australia 1994. SDC 101006b, January 2016. Map courtesy of the Spatial Data Centre, Great Barrier Reef Marine Park Authority, reformatted for publication with permission. © Commonwealth of Australia (GBRMPA) 2017.

The premise of SCP is that evidence-based advice promotes transparency and accountability when managing difficult and value-laden decisions. Following this line of logic, our interest lies in the degree to which SCP is actually aiding decision makers and how, when, and where it is most likely to lead to conservation impact.

SCP projects can be costly and time consuming to develop (Pressey & Bottrill 2009), and in situations requiring rapid action, queries have been raised about when and where the delay and cost required for additional data gathering and planning is justifiable (Knight et al. 2011c). Perhaps most concerning are questions around the degree to which SCP projects influence real-world decisions, and concerns about the feasibility of their recommendations being adopted and implemented (Knight et al. 2008). One explanation for these uncertainties is the lack of information about the outcomes of SCP projects and a shortage of rigorous **impact evaluations** (Bottrill & Pressey 2012). Without such evidence, conservation organisations and government agencies will not only struggle to argue for investment in planning exercises but will also continue to operate in uncertainty about the most **effective** approaches.

This review will focus on evidence for the outcomes of SCP, rather than the underlying principles and technical approaches commonly employed when developing plans, which have been extensively covered in this journal (Sarkar et al. 2006) and elsewhere (Margules & Sarkar 2007; Moilanen et al. 2009; Kukkala & Moilanen 2013). We describe the background and ontology of SCP, before reviewing trends in the evaluation of conservation planning

interventions. We then provide an exploration of how conservation impact can be defined and measured, as well as a review of new initiatives in this area for SCP. Finally, we reflect on the framing of SCP as a 'challenging' intervention and make recommendations of alternative approaches for impact evaluation and information sharing across the discipline.

The ontology of systematic conservation planning

Conservation planning is "the process of making informed conservation decisions" (Groves & Game 2016a). Approaches to allocating conservation resources vary widely, from *ad hoc* to highly structured decision-support such as SCP. SCP refers to a structured, consultative process for choosing between, locating, configuring, and implementing conservation actions where: (a) the benefits of conservation actions are specified either as threshold amounts of natural features to be represented or as continuous functions with increasing amounts of features; and (b) the outputs are one or more optimal or near optimal sets of spatially bounded conservation actions (McIntosh et al. 2016; Paper 2).

The first published instance of a reserve selection algorithm, the precursor to SCP, was a simple iterative algorithm calculated by hand to assess conservation options for plants in Tasmania (Kirkpatrick 1983; Pressey 2002). In subsequent years the approach has spread across the globe. Between 1980 and 2011, 1,834 articles were published which made reference to SCP or related themes (based on a keywords search conducted in Web of Science) (Kukkala & Moilanen 2013) and a popular SCP software package, Marxan (Ball et al. 2009), was downloaded by over 6,700 users from 184 countries over the five years between August 2011 and July 2016 (Watts & Possingham 2016). As an example, one of the most recently implemented conservation areas designed using SCP is Tun Mustapha Park, an almost 1 million ha marine reserve in Malaysia, gazetted in May 2016 (Weeks et al. 2014; Sabah Parks 2017).

In contrast to the explicit scoring or ranking approaches to identifying conservation priorities widely promoted in the 1970s (Pressey & Nicholls 1989), the goal of SCP has always been to identify emergent properties of sets of areas. Initially this was expressed through **complementarity** between areas (Margules & Pressey 2000; Justus & Sarkar 2002) but, increasingly, the focus is also on connectivity (Magris et al. 2014). The core ecological principles underpinning SCP are **representation** and **persistence**, with the latter often approached through connectivity of multiple species and habitats across landscapes and seascapes. For further details and related terms, see (Sarkar et al. 2006; Margules & Sarkar 2007; Kukkala & Moilanen 2013).

Early on, SCP was envisaged as a six stage process intended to guide conservation area selection (Margules & Pressey 2000). Following this model (Figure 1.2a), the first stage is data collection. A strength of the SCP process is the variety of data types that can be incorporated; biological elements, such as species distribution data, spatial surrogates for biodiversity, and metapopulation dynamics (Sarkar et al. 2006), can be considered alongside social, financial or political constraints and opportunities, such as the willingness of a local population to conserve an area (Knight et al. 2011b; Ban et al. 2013). For the second stage, specific quantitative **objectives** must be set, indicating how much of each biodiversity feature should be represented, often combined with quantitative or qualitative objectives for aspects such as connectivity, or the shape or size of conservation areas. Stage three consists of reviewing the extent to which the objectives are met by existing conservation area networks.

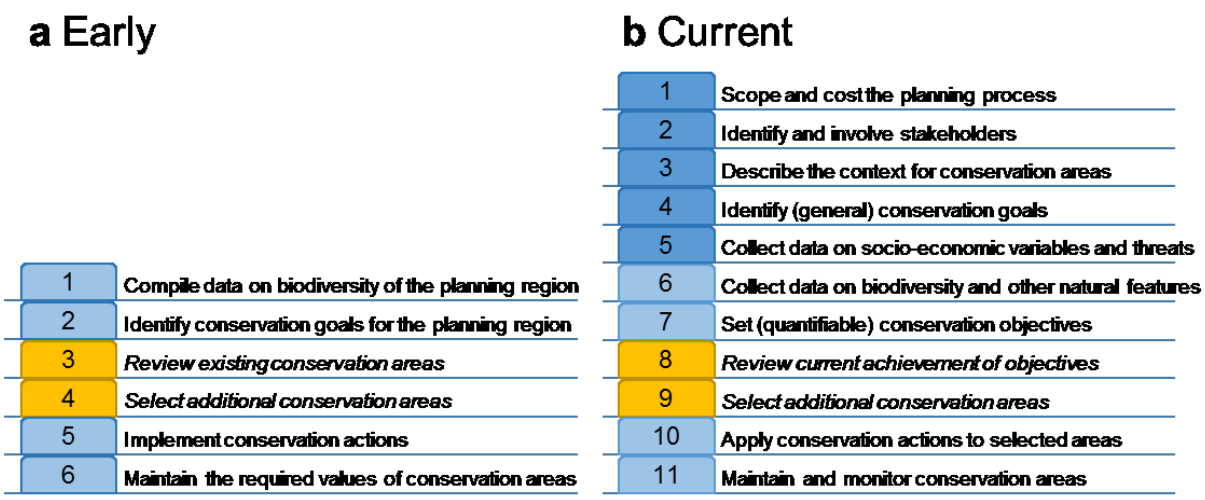


Figure 1.2: The primary stages of systematic conservation planning (SCP). SCP is an iterative, rather than a linear process, with feedbacks in light of new data or logistical considerations, and with stakeholder engagement throughout. (a) outlines an early six-stage view of the SCP process (Margules & Pressey 2000) and (b) represents the dominant framework available for SCP, modified from (Pressey & Bottrill 2009), with greater emphasis on implementation considerations. Light blue boxes indicate equivalent stages in a and b; dark blue indicates novel stages in b. The stages in orange refer to the spatial conservation prioritisation stages, typically involving special-purpose software.

Available data are then analysed (stage four) using an algorithmic approach in decision-support software, to produce sets of priority areas for the expansion of the conservation area network. The most widely used purpose-built software packages are Marxan (Ball & Possingham 2000), C-Plan (Pressey et al. 2009) and Zonation (Lehtomäki & Moilanen 2013). This step can also be done by hand or manually using GIS software, but doing so is only feasible for small areas or less complex plans.

Stages 3 and 4 together are often referred to as conducting a "**spatial conservation prioritisation**"/"prioritisation" or "conservation assessment" (in this article the former is used) (Wilson et al. 2009). Two fundamentally distinct applications are typically encountered when conducting prioritisations: the "minimum set covering" problem (Camm et al. 1996) in which the whole set of target features (e.g. species) is represented whilst minimising some other factor (e.g. cost), and the "maximal covering" problem in which the selected set of target features is

some maximised subset of the whole, subject to a ceiling on conservation resources (Williams et al. 2005).

Following this, in stage 5, appropriate management activities must then be identified and implemented, often comprising expanding an existing conservation area network. Finally, the network must be actively managed to maintain the contributions of conservation areas to the pre-determined objectives (stage 6).

Since the 2000 envisioning of SCP (Margules & Pressey 2000), numerous other operational models have been proposed that include iterative elements and increasing number of stages (Knight et al. 2006b; Sarkar et al. 2006; Pressey & Bottrill 2009; Sarkar & Illoldi-Range 2010). One recent articulation includes eleven primary stages (Pressey & Bottrill 2009; Figure 1.2b). The focus on implementation has been expanded to include greater consideration of stakeholder engagement, reviewing the local context, and incorporating socio-economic data from the outset (Steps 1-5 in Figure 1.2b), better reflecting SCP as a social process.

The iterative aspects were included because SCP was increasingly seen as part of an adaptive process, responding to changing scenarios, novel data, and reviews of the success of activities, all based on the assumption that planning recommendations emerging from adaptive decisions are more likely to be effective (Conservation Measures Partnership 2013). Overall the addition of implementation-orientated stages in the eleven stage model reflect an increased recognition that "effective conservation planning is fundamentally a practice, rather than a science" (Knight et al. 2013).

The scope of problems addressed has also expanded beyond the initial conceptualisation of SCP as "reserve selection". In addition to the design of new conservation areas, SCP is increasingly applied to diverse off-reserve mechanisms, including fire management and control of invasive species (Wilson et al. 2007). Other applications focus on restoration (Wilson et al.

2009) and the allocation of management actions within established protected areas. Prioritisations can also be used in non-spatial cases, such as the prioritisation of threatened species (Joseph et al. 2009), however we will focus on spatial applications for the purposes of comparability between projects.

The expansion of SCP has given rise to multiple terms with overlapping definitions and unclear distinctions. There are different schools of thought for terms including "goals", and "objectives", here we follow (Pressey & Bottrill 2009), but confusingly the term "targets" has been used in the wider literature to refer to both conservation features of interest and the objectives for those features. As we will explain throughout this article, there is also confusion between "systematic conservation planning" and "spatial conservation prioritisation".

Spatial conservation prioritisations can be conducted as stand-alone exercises to investigate the influence of types of data, not necessarily intended for implementation or application in a broader SCP process. Yet their similar terminology, three-letter acronyms, and map-based outputs often lead to prioritisations and the whole SCP process being confused. This confusion complicates the challenge of conducting impact evaluations for SCP, when a variety of decision-support exercises are referred to with the same name. In order to ensure a comparison of like with like, clear definitions must be used and individual projects carefully characterised prior to any evaluation. In this article, we use SCP exclusively to refer to broader, consultative planning process focused on implementation (but which include prioritisations) (Figure 1.2b), as distinct from prioritisation exercises, which may or may not be intended for direct implementation.

Principles of impact evaluation

Impact evaluation is primarily focused around identifying the intended and unintended consequences of an intervention (Leeuw & Vaessen 2009). Working towards conservation impact requires a clear understanding of what is to be achieved, and how to determine when conservation goals are reached; in other words, it requires a clear definition of what impact is meant to indicate. This knowledge alone, though, is insufficient; it is also necessary to hypothesise how proposed actions will lead to the desired impacts. This section expands on these considerations and suggests reasons for the deficiency of impact evaluation studies of SCP.

Defining impact

Consider a hypothetical SCP project plan to prevent the extirpation of a native species by habitat loss, by providing advice on where to establish a new protected area. We begin by defining the SCP project as an **intervention**. We refer to the change in the amount of habitat protected as a measurable product of the intervention – an **output**. The assumed or measured degree to which the native species responds to the output is the **outcome** of the intervention. But nothing up to this point actually measures the effectiveness of the intervention, which can only be judged on the difference between outcomes across a **counterfactual** comparison. We define this counterfactual difference as the **impact** of the intervention. This terminology follows (Pressey et al. 2015).

Conservation plans must do several things to maximise conservation gains: achieve explicit objectives; involve stakeholders and minimise harm to people; promote transition to implementation; deliver cost-effective outcomes; and make a difference to biodiversity and/or people (have conservation impact). Evaluations should extend beyond the measurement of whether objectives have been met in areas identified as priorities (Knight et al. 2008). They

should also consider the cost and efficiency of reaching these objectives and the effects of using cost-effectiveness analysis and threat reduction assessment (alongside socio-cultural and ecological considerations) (Laycock et al. 2013). In the context of SCP, conducting evaluations in the form of the representativeness of a proposed conservation area can give misleading results for conservation impact. Representativeness in theoretical, or even implemented, conservation areas can be a weak measure of impact because it does not necessarily reflect consequences for biodiversity protection (Pressey et al. 2015) e.g. species persistence on the ground.

Impact evaluation addresses a critical question: what would have happened without the intervention? Impact evaluation, rather than measuring outcomes, is the only way to attribute apparent changes in the condition of biodiversity to a planning exercise (Ferraro & Hanauer 2014) because it allows distinguishing the effects of the planning process from other external factors. For example, the outcome of increased native species in a protected area could be due to influences such as weather or climatic events, not necessarily the reduction in habitat loss. Consequently, an outcome associated with a conservation plan should merely be reported as such – an outcome, possibly reflecting factors other than the planning process, rather than a verified impact.

An evidence hierarchy exists in the evaluation literature, with double-blind randomised control trials commonly regarded as the gold standard for establishing attribution, particularly in the medical and health sciences literature (Deaton & Cartwright 2016). Such experimental approaches are often less practical or desirable for conservation interventions, for which quasi-experimental and qualitative analyses can also yield valuable information (Ferraro & Hanauer 2014). Ultimately, the most important considerations are the design of the evaluation, a strong conceptual understanding of chains of causal inference (and an attempt to verify these with

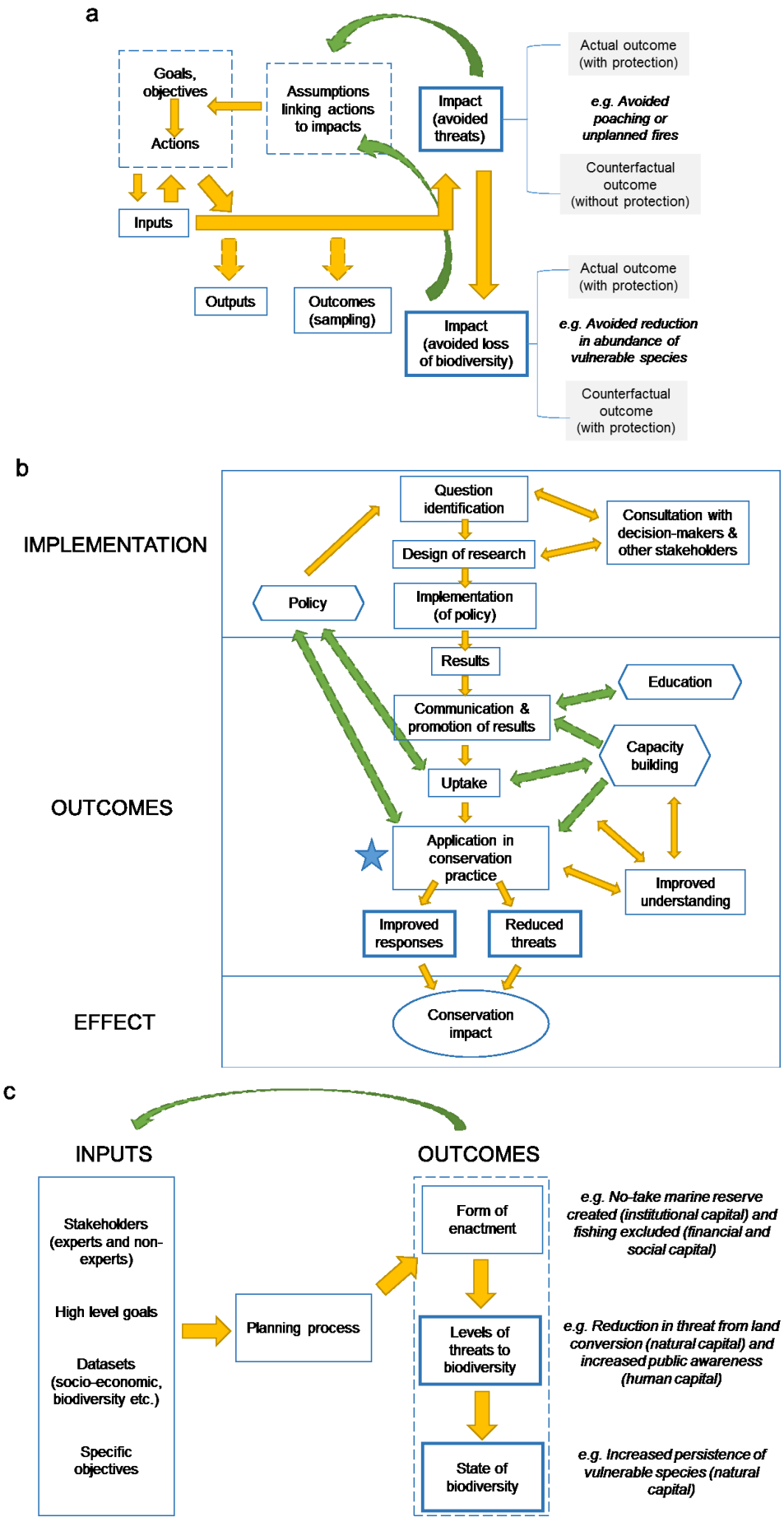
data), good knowledge of the local context, and elimination of alternative explanations for observed outcomes (Ferraro & Hanauer 2014).

Theories of change for systematic conservation planning

Understanding how and why an intervention led to conservation impacts is almost as important as understanding the impacts themselves, particularly if there is an interest in using the findings to inform interventions in other contexts. Theories of change (also known as results chains and logic models) are explicit statements about the expected effects of an intervention, usually presented in the form of diagrams showing causal links (Patton 2008a; White 2009; Margoluis et al. 2013). They are rarely published in SCP, the documentation of which is often littered with unjustified assumptions, even simply that the outputs can and will receive vital stakeholder and political support (WWF European Alpine Programme 2005).

Conservation planners (and conservation scientists generally (Fisher et al. 2014)) must improve efforts to account for the likelihood of intended actions being applied (Knight et al. 2010, 2011a), and the influence on biodiversity of pressures that can be only partially mitigated, or perhaps not mitigated at all, by managing the spatial arrangement of conservation areas. Beyond this kind of analysis, theories of change are also needed to justify assumptions about how decisions at each stage of the planning process can influence the impacts of projects. For example, high-level political lobbying could increase funds available for an intervention, perhaps to increase the area of land added to a conservation area network, which could result in greater conservation impacts (Pressey et al. 2015). This lobbying would be a non-spatial intervention outside the scientific dimensions of the planning process but one that could have major implications on impacts for biodiversity. Theories of change form the basis of any impact evaluation: Did what was expected to happen occur, and did it occur because of actions associated with the project or external factors, either anticipated or unanticipated (Patton 2008a; White 2009)?

The different frameworks outlined in Figure 1.3 highlight an important challenge for impact evaluation of SCP – that a single, standardised theory of change would not meet all the potential uses of such a model, nor capture all the complexities of planning. This is a major barrier to the widespread development of impact evaluations of SCP. It has been advised that transdisciplinary teams work collaboratively to ensure appropriate design of theories of change for each application and to thoroughly explore the feasibility of conservation actions in a given context (Raymond & Knight 2013).


a
Goals, objectives
Actions
Assumptions linking actions to impacts
Impact (avoided threats)
Actual outcome (with protection)
e.g. Avoided poaching or unplanned fires
Counterfactual outcome (without protection)
Inputs
Outputs
Outcomes (sampling)
Impact (avoided loss of biodiversity)
Actual outcome (with protection)
e.g. Avoided reduction in abundance of vulnerable species
Counterfactual outcome (with protection)
b
IMPLEMENTATION
OUTCOMES
EFFECT
Question identification
Consultation with decision-makers & other stakeholders
Design of research
Policy
Implementation (of policy)
Results
Education
Communication & promotion of results
Capacity building
Uptake
Application in conservation practice
Improved understanding
Improved responses
Reduced threats
Conservation impact
c
INPUTS
OUTCOMES
Stakeholders (experts and non-experts)
High level goals
Datasets (socio-economic, biodiversity etc.)
Specific objectives
Planning process
Form of enactment
Levels of threats to biodiversity
State of biodiversity
e.g. No-take marine reserve created (institutional capital) and fishing excluded (financial and social capital)
e.g. Reduction in threat from land conversion (natural capital) and increased public awareness (human capital)
e.g. Increased persistence of vulnerable species (natural capital)

(Previous page) Figure 1.3: Theory of change frameworks (or logic models) can be developed at different scales or specificities, as demonstrated by these three examples. Solid yellow arrows indicate directions of influence and green arrows indicate feedbacks and dashed yellow arrows indicate incidental components. (a) Framework of protected-area planning directed at achieving impact, focusing on the examples of avoided threats and avoided loss of biodiversity [adapted from Pressey et al. (2015) (CC BY license)]. In this model, outputs and outcomes of sampling are incidental. (b) Framework for research and conservation planning (adapted with permission from Kapos et al. (2008, appendix S1)). Inputs from other types of conservation activities are shown in hexagons and the blue star indicates the 'key outcome' in relation to reducing threats and the improving responses of conservation targets. (c) Theory of change developed to guide the design of, and data extraction requirements for, a meta-analysis of evaluations of systematic conservation planning (SCP) (reproduced with permission from McIntosh et al. (2016)). Hence, the focus is on identifying inputs and outcomes of SCP, rather than on identifying impacts (counterfactuals and impacts are excluded) or identifying the specific pathways between inputs and outcomes. The first framework (a) is most suitable for physical interventions (protected areas, constructing fencing etc.) and employs clear counterfactuals due to the focus on impacts. The theories of change in the second (b) and third (c) frameworks represent more of the stakeholder ecosystem - less on using counterfactuals to identify impact - and demonstrate more (b) and less (c) specified causal pathways during the planning process. These different frameworks demonstrate the range of scales at which planning (and evaluation) can operate and highlight that a single pluripotent theory of change for SCP is impossible to conceive. This is a major barrier to widespread impact evaluations of SCP.

The evaluation knowledge gap

It is surprising that there is currently no definitive record of how many SCP projects have been developed, implemented, or evaluated or where they have been applied, and by whom. This is partly due to the relative youth of the discipline (Pressey 2002), lack of resources and obligations to report outcomes, and the time-lag associated with observing changes in the condition of natural assets (i.e. outcomes). However, the lack of impact evaluations of SCP may

have more to do with the absence of an agreed system and standardised culture of recording such information. In the academic literature to date, the sub-discipline concerned with implementing and evaluating SCP projects (Smith et al. 2009; Pressey et al. 2013) has been the poor cousin of the sub-discipline concerned with developing novel methods to improve the datasets, algorithms, and computational tools that underpin prioritisations (Knight et al. 2013). The latter research is essential and has led to great advances in the past few decades, but there is a need to consolidate information on developing planning processes that result in positive (or zero, or negative) conservation impacts, and how best to translate evidence-informed SCP recommendations into on-the-ground action. There is also the potential for evaluation and methods to inform each other, given that not every analytical approach or dataset will necessarily add value to outcomes on the ground, and some technical advances (e.g. computationally-intensive approaches or very large datasets) could conceivably hinder implementation.

Very few impact evaluations of SCP projects have been published in academic journals (Bottrill & Pressey 2012; McIntosh et al. 2016) and, of these evaluations, most have focused on a particular time period or geographic region (Knight et al. 2008; Bottrill & Pressey 2012; Kullberg & Moilanen 2014), or exclusively on analyses of the academic literature rather than the grey literature. Despite success being perceived differently by different stakeholders (Rogers 2008; Bottrill & Pressey 2012), most reported evaluations have focused on the views of academics or anecdotal reports from the conservation planners involved in developing the SCP in question, rather than the perceptions of other people involved or affected by the planning process (Knight et al. 2008; Osmond et al. 2010; Weeks et al. 2014).

It is tempting to attribute the knowledge gap on impact evaluations of SCP to barriers preventing practitioners publishing, lack of knowledge about evaluation, or scarce resources for evaluation. While these are real limitations, it is important to recognise that the knowledge gap

does not necessarily reflect an unwillingness to conduct impact evaluations. Other important factors are misunderstandings of real measures of impact (Pressey et al. 2015), the logistical challenges associated with the complexity of conservation planning, fear of failure (Knight 2009), and infeasible expectations around applying only the most rigorous impact evaluation methodologies. Furthermore, there is currently no standardised protocol for undertaking impact evaluations of SCP projects (Bottrill & Pressey 2012, see also Figure 1.3). Evidence shows that practitioners generally know what is required to develop robust evaluation designs but that limited time or continuity of funding constrain the application of such programs (Curzon & Kontoleon 2016). The five most common barriers to implementing high-quality impact evaluation methods as reported by practitioners in the conservation policy field were: lack of funding, poor availability of baseline data, time constraints, lack of forward planning, and absence of a suitable control group (Curzon & Kontoleon 2016).

There is a growing body of evidence on the impact of protected areas for biodiversity conservation (Geldmann et al. 2013; Oldekop et al. 2015) as well as on their social impacts (Schreckenberg et al. 2010) and management effectiveness (Hockings et al. 2006; Coad et al. 2015), all of which hold lessons for the evaluation of conservation planning processes. But while impact evaluation of specific interventions, such as one or more protected areas, is slowly gaining momentum, assessing the effectiveness of a planning or decision-support process, involving multiple potential interventions, is more difficult. It is plausible to want to measure outcomes at various stages of the planning process (e.g. during a consultation process or upon a conservation area being written into legislation) or at different time periods following the completion of an SCP project (the recovery of a threatened plant community could take several decades to observe).

When interpreting the results of an evaluation of a planning process, there are likely to be many confounding factors, such as climatic changes, other human impacts (e.g. non-compliance with

no-take marine reserves) (Bergseth et al. 2015), invasive species, differential stakeholder buy-in (Knight et al. 2011b), and political resistance, all of which make it difficult to determine the difference made by the planning process specifically. Finally, logistical considerations are also important. Planning is often a one-off activity: organisations and people frequently move on after project completion, when the organisational focus and associated resources disappear, so those best positioned to document or evaluate planning processes may not be able, or may have moved into completely different roles (Pressey et al. 2013).

State of knowledge about the impacts of systematic conservation planning

Existing perspectives on evaluating systematic conservation planning

Questions about the impacts of SCP sparked debates in the 2000s, primarily about the suitability of some of the academic outputs for on-ground implementation (Cowling et al. 2003; Knight et al. 2006a, 2010) and the dangers of neglecting genuine engagement with land owners and local communities throughout the process (Biggs et al. 2011; Knight et al. 2011c, 2013).

In one of the first studies to attempt to determine the impact of the SCP discipline, the proportion of spatial conservation prioritisations designed for direct implementation was assessed (Knight et al. 2008). A literature search was conducted within academic journals published between 1998 and 2002 (this study did not include grey literature) and questionnaires were sent to the first authors of each publication. Knight et al. (2008) found that two thirds of the prioritisations they assessed did not deliver conservation action, primarily because researchers did not plan for implementation. Ten years on, this trend remains (Kullberg & Moilanen 2014). A limitation of the 2008 study was that it focused on prioritisation exercises, rather than examples of the broader SCP processes. Some academics have defended baseline research and prioritisations as distinct from applied studies, and much

of the progress in applications of SCP has built on necessary basic research into spatial prioritisations. However, academic publications about prioritisations continue to outnumber those about SCP implementation and evaluation.

An alternative approach is to measure the characteristics of the spatial prioritisations with regards to implementation. By focusing on the type and sources of research most often translated into the implementation of conservation projects, Smith et al. (2009) argued that the more relevant analyses for on-ground conservation were fine-scale prioritisations that included cost data and biodiversity data for more than one taxon. A simple scoring system was used to investigate the likelihood of publications on spatial conservation prioritisations having relevance for implementation. Based on the authors' scoring criteria, almost half of all academic articles failed to score any points for relevance, whereas those that had at least one author affiliated with a government conservation agency had the highest summed scores (Smith et al. 2009).

As previously discussed, whether implementation occurred can be informative, but it is not a holistic measure of success. Implementation indicates that a planning exercise has had some consequences, but not necessarily whether it led to impacts for species, habitats or local communities. SCP is also notable in having diverse outcomes that are not conditional on implementation. For example by familiarising stakeholders with planning processes, raising expectations about objectives and results, and influencing policy and legislation (Bottrill & Pressey 2012), an SCP exercise might provoke positive change, and even potentially have impact, even if the proposed actions were not in fact implemented.

This diversity of potential benefits from SCP was highlighted in another, case-study approach. Bottrill et al. (2012) used qualitative methods to examine the benefits reported by those employing SCP approaches at The Nature Conservancy, an international NGO with extensive expertise in developing and applying SCP (see Box 1).

The majority of these and other published impact evaluations of individual SCP projects involve the views of staff and academics involved in the planning process (e.g. Osmond et al. 2010; Weeks et al. 2014). While useful as a starting point to share information on procedures and observed short-term outcomes, these studies are very vulnerable to bias and, by our definition, are not designed to demonstrate impact.

A major advantage of SCP is that it involves setting specific objectives at the start of the planning process, and counting the number of objectives met can be informative when assessing project outcomes e.g. (Fernandes et al. 2005). This is particularly useful for comparisons with historical patterns (Venter et al. 2014), sites selected at random (Kuempel et al. 2016), or expert-derived scenarios on what could have happened in the absence of the SCP exercise (Visconti et al. 2015). Given the relative ease of conducting such evaluations, these approaches provide considerable opportunities to integrate counterfactual thinking when assessing outcomes, if not conservation impact.

Box 1: Evaluating social, financial, and institutional benefits of systematic conservation planning at The Nature Conservancy

In a review of five SCP projects undertaken by The Nature Conservancy, Bottrill et al. (2012) undertook document analysis and 17 semi-structured interviews with senior planning staff to explore the interviewees' perceptions of: a) the purpose and intent of each planning process; b) the benefits according to aspects of natural, financial, social, institutional, and human capital; and c) the enabling and constraining factors that influenced the realisation of these benefits (broken into process, inputs, and context).

Natural capital benefits such as the reduction in threats to biodiversity were not reported as having been fully achieved in any project. Improvements in human and institutional systems such as social interactions, attitudes, and institutional knowledge were the most frequently reported. This study provided in-depth insights into the factors that constrained the realisation of benefits (primarily social and political aspects of the region) and enabled the delivery of benefits (most importantly design of the process, leadership, funding, and timing).

Overall, Bottrill et al. (2012) demonstrated the value of, and need to measure proximal benefits when evaluating SCP projects, particularly because intended conservation outcomes for natural capital are difficult to monitor in the short term.

Guidance on designing systematic conservation planning projects

In the absence of a reference library of rigorous impact evaluations of SCP, it is still worth noting trends in commonly reported outcomes or traits affiliated with reportedly effective and ineffective planning exercises. A range of literature exists on what makes a good planning process (Driver et al. 2003; Cowling & Pressey 2003; Knight et al. 2006b, 2006a, 2009, 2013; Biggs et al. 2011; Groves & Game 2016a), although much of this is based on experience-based

predictions, not on demonstrated impact. These can still provide useful indications of factors influencing planning processes, and aid in the identification of potential causal pathways and important external variables. The *Open Standards* developed by the Conservation Measures Partnership is also a valuable resource when designing projects (see Box 2).

Box 2: Open Standards for the Practice of Conservation

The *Open Standards for the Practice of Conservation*, developed by the Conservation Measures Partnership (CMP) is an open source resource intended to "combine principles and best practices in adaptive management and results-based management from conservation and other fields" (Conservation Measures Partnership 2013). The general principles of the *Open Standards* are to: involve stakeholders; develop and cultivate partnerships; embrace learning; document your decisions; and adjust as necessary (Conservation Measures Partnership 2013). A five-step project management cycle advocated by the CMP is as relevant to SCP as to any other conservation project: 1) conceptualise the project vision and context; 2) plan actions and monitoring; 3) implement actions and monitoring; 4) analyse data, use the results, and adapt; and 5) capture and share learning. Broad adoption of the *Open Standards* (including by world's two largest conservation NGOs) has been shown to achieve many of the intended outcomes, including increased stakeholder participation, sharing of lessons and implementation of actions. However, similarly to SCP, there have been no counterfactual studies to prove the *Open Standards* have resulted in conservation impact (Redford et al. 2014).

Outcomes commonly associated with reportedly successful planning projects include: multi-stakeholder collaborations, integration of local and scientific knowledge, capacity building, the use of multiple-use zoning, and participation in learning and governance networks (Knight et al. 2006a; Weeks et al. 2014). In addition to these traits, priority setting requires explicit and defensible objectives to be developed at the start of a planning process, not only for representation and configuration, but for outcomes and impacts. Spatial prioritisations should

also incorporate economic, political, and social constraints on actions and a consideration of complementarity. The principles supporting collaborative and transdisciplinary approaches to conservation planning include accountability, adaptability, social learning, and pragmatism, added to genuine engagement with multiple types of knowledge (local, scientific, and traditional) (Knight et al. 2013).

The importance of several key contextual factors, such as the presence of local champions (Knight et al. 2010), has been identified, and the need to embrace opportunism in the selection of conservation areas or actions, debated (Knight & Cowling 2007; Pressey & Bottrill 2008). However, the relative importance of social and governance factors is still unclear and probably varies across contexts (Ban et al. 2013). Universally applicable solutions are elusive and the technical challenges of planning are less severe than the operational challenges (Knight et al. 2013; Raymond & Knight 2013).

Emerging studies

The above-mentioned knowledge gaps and challenges for the evaluation of conservation planning have led to several ongoing projects designed to collate and review existing information about the applications and effectiveness of SCP worldwide. J.G. Álvarez-Romero et al. (2018) have compiled a centralised collection of SCP projects and spatial prioritisations. This database currently includes all marine planning exercises documented in the primary literature, although it does not distinguish between spatial prioritisations and full SCP processes. The authors designed the database to allow future inclusion of all terrestrial and freshwater prioritisations, as well as to connect this to other databases such as the World Database on Protected Areas (http://www.protectedplanet.net). This will be a significant resource given that there is currently no accurate estimate of how many prioritisations exist and only approximate information on where they are being developed and by whom (Knight et al. 2008; Kukkala & Moilanen 2013). The database will provide a means to extract statistics and

trends, generate maps, and encourage the standardisation of reporting. Álvarez-Romero et al. extracted data on an extensive suite of criteria from 155 marine prioritisation studies published over the past 15 years. They were able to demonstrate that five countries (Australia, United States, Canada, United Kingdom, and South Africa) accounted for 80% of all published prioritisations, suggesting a strong geographical bias in terms of activity and expertise (J.G. Álvarez-Romero et al., manuscript in preparation). This geographical bias is consistent with the finding that 40% of studies published in three top conservation journals between 2011 and 2015 were carried out in only three developed countries (United States, Australia, and the United Kingdom) (Di Marco et al. 2017).

McIntosh et al. (2016; Paper 2) are developing a **systematic map** to identify the extent and distribution of evidence on the conservation outcomes of SCP (projects which are prioritisations alone, are excluded from this study). This involves replicable searches of publication databases (e.g. Web of Science), search engines (e.g. Google Scholar), and online repositories (e.g. conference proceedings) and targeted searches of relevant organisational websites. The grey literature has never before been thoroughly searched, despite the large number of conservation organisations that are unlikely to publish all (or even much) of their output in academic journals. Standardised data about the objectives and characteristics of each SCP project, the impact evaluation study design, reported outcomes (according to natural, social, human, financial, and institutional capitals), and context of the evaluation are being compiled in a database, creating the most thorough international repository of impact evaluations of SCP available. It is intended that this will be cross-compatible with the aforementioned database being developed by Álvarez-Romero and colleagues, which does not yet extend to include information on implementation and impact evaluation.

S.P. Lloyd et al. (manuscript in preparation) [NB by thesis submission this paper had been published: (Sinclair et al. 2018)] are conducting a global survey of conservation plans with the

aim of understanding who is creating them, how, where, and why. Representing one of the first explorations of SCP projects published in academic journals and the grey literature, this study aims to understand the relationship between approaches to conducting SCP, challenges faced, and, ultimately, whether or not the projects led to implementation. A literature review has been used to populate a comprehensive list of SCP projects mentioned in academic journals, the authors of which have then been invited to participate in the survey. Due to the absence of an available database, a snowballing approach has also been used to reach a broad spectrum of SCP developers from the grey literature.

Another relevant study is a recently completed survey into the use of decision-support tools in marine spatial planning (MSP) practice which was conducted as part of the BALTSPACE project (http://www.baltspace.eu/). BALTSPACE was set up to explore integration challenges (for example across disciplines, between stakeholders, across political boundaries) in marine planning in the Baltic Sea region. Similar to the work by Álvarez-Romero et al. and the survey developed by Lloyd et al., the aim of this project was to assess the degree to which decision-support tools are used in marine spatial planning globally and why practitioners might or might not choose to use them.

When it comes to shared learnings, coordination between these and similar projects is key, as is the accessibility of the findings. The resources required to screen potentially relevant studies, conduct surveys, and extract relevant information are not insignificant, and the opportunities for comparing complementary approaches and pooling their findings are substantial. There remain significant barriers, however, in the form of inconsistent terminology and definitions (in particular the now-ubiquitous conflation of SCP and spatial conservation prioritisation) which will need to be overcome before rigorous inference about impact can eventually be made from these resources.

Analysing challenging interventions

Conservation planning problems are "inherently wicked" (Rittel & Webber 1973) as there is no definitive formulation of the problem, there is no clear end point or distinct solution, there are no obviously right and wrong decisions. Every implemented solution has consequences, and every conservation planning scenario is largely idiosyncratic. The early conceptions of SCP (Margules & Pressey 2000) as a series of stages, did not sufficiently capture this complexity. Although not intended to present the process as being strictly linear, it is interesting to note that these stages were analogous to the 'problem definition, information gathering, and analysis and synthesis and solution' approach, which Rittel & Webber particularly highlight as being unsuitable for addressing wicked problems (Rittel & Webber 1973).

We are not the first to suggest that this framing is probably no longer ideal for conservation planning (Game et al. 2014). However, it may be necessary to take the advice that "[conservation] problems are never solved. At best they are only re-solved – over and over again" (Rittel & Webber 1973, p160). This is not to say that evidence-based policy should be rejected as a goal of conservation planners, rather that it is necessary to recognise that "evidence is not based on a simple mechanistic view of the relationship between interventions and outcomes" (Harrison 2000).

Instead, it is necessary to develop a more nuanced conceptual understanding of SCP as a type of intervention, to guide the impact evaluation process. Drawing from programme theory (Rogers 2008), it is apparent that SCP does not fit a 'simple logic model' (e.g. following inputs, processes, outputs, outcomes, and impacts). SCP is 'complicated', in that it often concerns multiple components (e.g. multiple concurrent causal pathways in different contexts, and may involve multiple governance agencies) but overall, it is 'complex'; exhibiting feedback effects throughout a planning process, and outcomes can emerge during the process of design rather

than only at a discrete end-point (Margules & Sarkar 2007; Bottrill et al. 2012; Pressey et al. 2013; Wendt et al. 2016). Unfortunately, the most difficult interventions to evaluate are those that contain both complicated and complex elements (Rogers 2008), which may explain why so few impact evaluations of SCP have been conducted to date. Identifying the complicated and complex elements of SCP is one way of developing a theory of change to use when designing an impact evaluation for a specific project.

Alternative approaches to impact evaluation for systematic conservation planning

SCP is a process, rather than simply one or more implemented conservation areas or actions. In SCP, as in many real-world conservation scenarios, true counterfactuals might be possible to observe only in rare, opportunistic circumstances. An example would be two similar, adjacent administrative regions but with only one adopting SCP approaches. Such opportunities to measure impacts should be seized when they arise but experimentally creating such circumstances is unlikely to be possible. However, site counterfactuals may be easier to find, and, as hypothesised by Bottrill & Pressey (2012), it has proven to be possible to assess where stakeholders locate conservation activities before and after SCP has been conducted, to determine the influence of the planning recommendations over subsequent conservation actions (Carter et al. 2014).

Existing methods for evaluating individual components of planning processes could also be explored, such as for stakeholder consultation activities, or the degree of collaboration between partner organisations. In fact, in related disciplines such as urban planning, it is common to employ several concurrent evaluation questions and approaches (Harrison 2000).

Rather than aspiring to some notion of 'best practice' impact evaluation for SCP, it might be best to promote an acceptable minimum standard for impact evaluations (Curzon & Kontoleon 2016) and to direct efforts to the recognition and management of patterns and trends (Game et

al. 2014). As a bare minimum, write-ups of how SCP projects were developed, and observations from practitioners of outcomes (both positive and negative) (Knight 2006), are promoted in publicly accessible reports and academic publications. Given SCP involves emergent outcomes, which can arise at various points throughout the process, it might be helpful to integrate an evaluator within the design team in what is called 'developmental evaluation' (Patton 1994). Ultimately, for complex interventions like SCP, multiple complementary methods, including 'softer' qualitative methods such as semi-structured interviews, will be necessary to capture an overall picture and key dimensions of the local context (Harrison 2000).

In addition to promoting a culture of reporting the outcomes, standardised approaches to reporting impact evaluation results will be necessary in order to compare studies. These should include study design, inputs, outputs, outcomes, and context (Table 1.1). This will help facilitate the development of a communal database of SCP projects and impact evaluations as proposed by Álvarez-Romero et al. (in prep.) and McIntosh et al. (2016).

Table 1.1: Ideal standardised reporting categories for impact evaluations of systematic conservation plans, modified from an existing data extraction template (McIntosh et al. 2016).

Metadata category	Specific details
Bibliographic information	Standard bibliographic details (author, date etc.), including publication type
Basic information about the conservation plan	Location of study (including GPS coordinates)
	Name of resultant conservation area or similar
	Type of organisation leading the planning process
	Size of area considered for the planning process (ha)
	Type of biome(s)
	Broad goals of the planning process
	Specific objectives set for the planning process
	Nature of stakeholder participation (including who participated)
	Type of actions considered in planning
	Cost of SCP development
Impact evaluation study design	Methods (a measure of study quality and rigor) e.g. experimental, quasi-experimental or non-experimental
Outputs, outcomes, and impacts	Reported outputs
	Reported outcomes of planning process
	Direction of change of outcome (positive or negative)
	Proportion of project objectives met
	Reported impacts (if the evaluation design is robust enough to allow for counterfactuals and attribution)
Context of the study	Location of lead author's organisation and type of organisation
	Purpose/rationale for the study (stated reasons for undertaking an impact evaluation)
Outcome pathways	Theory of change or logic model (if included)

Discussion

SCP is an influential discipline in shaping conservation investment and research, and as such, it is essential SCP be developed and implemented so as to maximise impacts for biodiversity conservation. Efforts are underway to develop substantive databases of SCP projects and their outcomes (McIntosh et al. 2016; Papers 2 and 4), and we hope that these developments will be

extended to include understandings of the causal chains that lead to those impacts. But these are only really the first stages of assessing true conservation impact, as opposed to the outcomes observed for some planning processes. Evaluating impact will require more reporting and monitoring, but also maximising opportunities for counterfactual evaluations. Evaluation could be aided by conservation planners articulating their theories of change, to enable follow-up assessments of whether expected outcomes were realised, or whether unintended outcomes arose. There is also a need for more qualitative approaches to impact evaluation, such as measures of perceived utility of planning processes (Bottrill et al. 2012), particularly where counterfactual approaches are deemed infeasible, because the former can be highly informative when appropriately conducted.

To further improve the quality and availability of rigorous impact evaluations of SCP processes, clear and consistent definitions are required, including consistent definitions of spatial conservation prioritisations as distinct from broader SCP processes. Standardised reporting of SCP attributes, including objectives and outcomes, would also aid comparisons between different planning contexts. In addition, those evaluating planning processes should be clear when referring to impact evaluation methods used so the reader can determine the study quality and correctly interpret claims of an SCP project having been successful or having achieved impact. Finally, centralised repositories of geo-located projects and associated evaluation records will be essential to track the continued expansion and influence of the discipline in shaping biodiversity conservation efforts globally.

Summary points

- Systematic conservation planning (SCP) is one of the most rigorous approaches for choosing between, locating and implementing biodiversity conservation actions.

- Despite the widespread influence and application of SCP, very few impact evaluations have been conducted, and there is much still to understand about how decision-support aspects of SCP lead to conservation impact.
- There are many challenges to evaluating a planning process. However, it is clear that the processes can be as important as any end-products, and outcomes can range widely, from social, human, institutional, and financial, through to those for natural capital.
- Emerging perspectives and studies on the implementation of SCP are opening up a shared understanding of when, where, and why it can influence conservation actions.

Future issues

- Improved use of theories of change and counterfactual analyses are required to further our existing understanding of how SCP can lead to conservation impact.
- Clarity is required in the use of key terms, such as “outcome” vs “impact” and “systematic conservation plan (SCP)” vs “spatial conservation prioritisation”.
- The creation and maintenance of centralised repositories of geo-located SCP projects and associated evaluation records will be necessary to track the continued expansion and influence of the discipline.

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2

Paper 2: What is the extent and distribution of evidence on effectiveness of systematic conservation planning around the globe? A systematic map protocol.

The published article is available online:

McIntosh EJ, McKinnon MC, Pressey RL, Grenyer R. 2016. What is the extent and distribution of evidence on conservation outcomes of systematic conservation planning around the globe? A systematic map protocol. Environmental Evidence 5:1–13. Doi: 10.1186/s13750-016-0069-4

This text reflects the accepted manuscript but may not include minor editorial changes made prior to publication.

Abstract

Background:

Systematic conservation planning involves the prioritisation of conservation actions to optimise biodiversity conservation outcomes whilst considering implementation challenges such as minimising costs. Thousands of systematic conservation plans have been developed around the globe (a popular software package, 'Marxan', has over 4,200 active users from more than 180 countries). However, the effects of systematic approaches on conservation actions and outcomes are not generally known, nor are the factors which distinguish effective from ineffective plans. Previous reviews of conservation planning outcomes have been limited in scope and to narrow time intervals and have revealed very few formal evaluations of plans. Given systematic approaches are widely perceived to offer the best chance to rapidly and efficiently achieve biodiversity protection targets, a thorough, up-to-date synthesis of the evidence is required.

Methods:

This protocol outlines the methodology for a systematic mapping exercise to identify retrospective studies measuring the effects of systematic conservation planning on biodiversity conservation at regional, national and subnational scales. Our primary research question is: What is the extent and distribution of evidence on the conservation outcomes of systematic conservation planning? Outcomes will be categorised according to types of capital: natural, financial, social, human and institutional, given the range of potential direct and indirect effects of systematic conservation planning on conservation outcomes. A comprehensive and repeatable search strategy will be undertaken, utilising a wide range of sources including grey literature sources and targeted searches of organisational websites and databases. Sources will be restricted to English language publications between 1983 and 2016. The resultant studies

will be screened using standardised inclusion and exclusion criteria and data from included studies will be categorised according to a standardised data extraction form. Information about the study design of relevant articles will be recorded to determine study robustness. A searchable database of studies will be made publicly accessible and available for updating in future. The results will be published in this journal and also presented as an interactive online resource to aid conservation planners in identifying impacts and outcomes of conservation plans.

Keywords

Conservation assessment; prioritisation; resource allocation; evidence synthesis; implementation

Background

The prioritisation of proposed conservation investments is essential to secure species, habitats and wilderness areas in urgent need of protection, given the limited resources available for biodiversity conservation (Bottrill et al. 2008). Internationally, governments have committed to the Aichi Biodiversity Targets of 17% of terrestrial and 10% of coastal and marine waters protected by 2020 (UNEP 2010) but current efforts are still falling short of these targets (Watson et al. 2014; Butchart et al. 2015). This situation necessitates transparent, rigorous and effective evidence-based policy approaches to enable decision makers to allocate limited resources strategically (Laycock et al. 2013), avoid the less efficient approaches of the past (Pressey 1994; Stewart et al. 2003; Joppa & Pfaff 2009) and, ultimately, achieve broader conservation goals.

Conservation planning is the process of identifying, configuring and managing conservation resources and actions to protect biodiversity and ecosystem services, most frequently in the design of protected area networks (Pressey & Bottrill 2009). Since its establishment in the early 1980s (Pressey 2002) and widespread uptake in the 1990s, the field of systematic conservation planning has grown rapidly and is widely considered to be the most influential paradigm for identifying spatial priorities for conservation investment (Margules & Pressey 2000; Knight 2006; Kukkala & Moilanen 2013). Systematic approaches have been applied in high-profile projects such as the designation and zoning of protected areas in the Great Barrier Reef, Australia (Fernandes et al. 2005) and the Cape Floristic Region, South Africa (Gelderblom et al. 2003).

Applications vary widely and systematic planning is often used to describe processes which involve some or all of the following stages; the setting of explicit conservation objectives, spatial biological data (typically multiple species and/or habitats), socioeconomic and other datasets,

stakeholder consultation (Pressey et al. 2013) and ultimately, the identification of priority areas for the allocation of conservation resources (Figure 2.1). The variation in the use of the term 'systematic' makes comparisons between plans difficult, hampering evaluation. A critical element in setting apart true systematic conservation planning from other types of conservation planning is the definition of an optimality criterion, against which alternative options can be compared (often completed as a 'spatial prioritisation' exercise, see Figure 2.1). (In real-world applications, strict algorithmic optimality (applied to initial data sets) may be modified to incorporate the preferences of stakeholders, who are sometimes involved interactively with data analysis (Knight et al. 2006b; Pressey et al. 2013).)

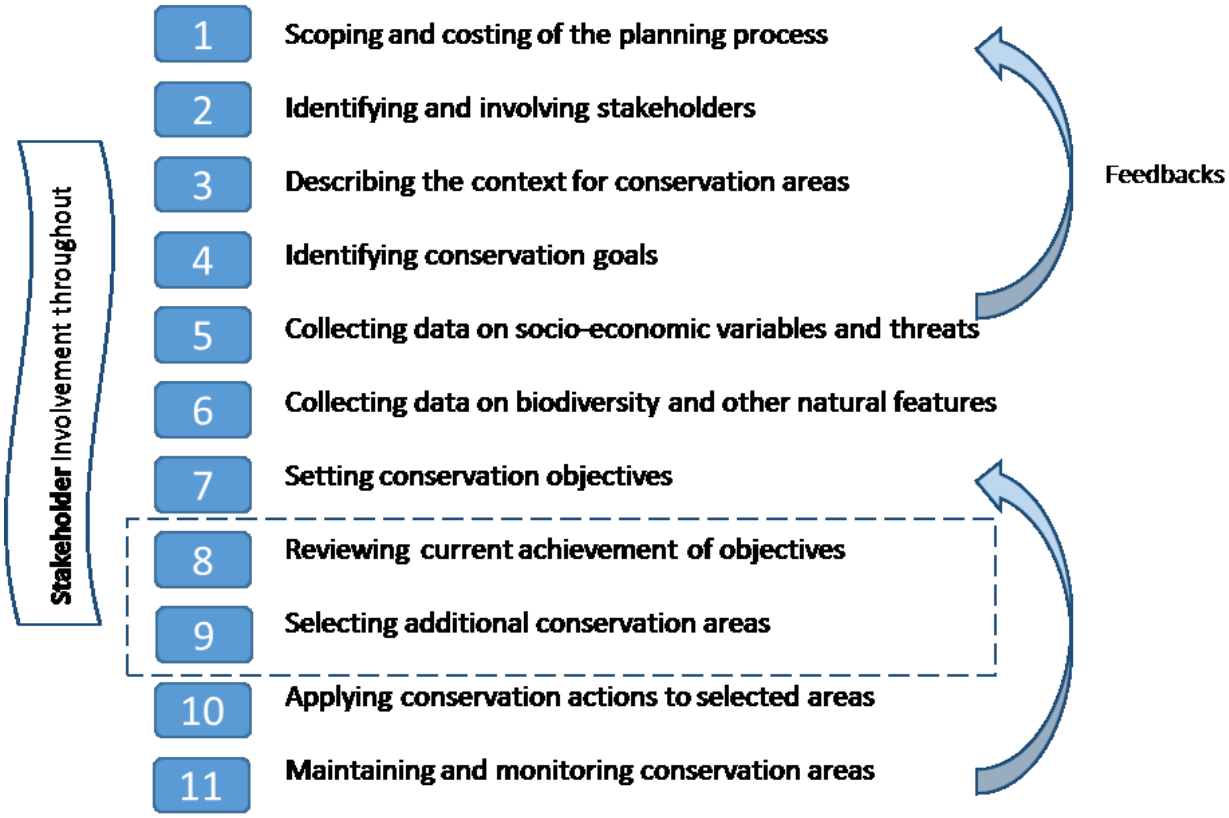

Figure 2.1: The primary stages of systematic conservation planning (SCP) (modified from Pressey & Bottrill 2009). This is an iterative, rather than a linear process, with feedbacks in light of new data or logistical considerations. The box around stages 8 and 9 indicates the spatial prioritisation stages during which computational decision-analysis tools are often used.

As an inclusion criterion for this systematic map, we therefore define systematic conservation planning as a process for locating and implementing conservation actions where: a) the benefits of conservation actions are specified either as threshold amounts of natural features to be represented or as continuous functions with increasing amounts of features; and b) the outputs are one or more optimal or near optimal sets of spatially-bounded conservation actions (Table 2.1). (This requires a definition of conservation actions, which we here define as legal demarcations and/or management interventions to promote the persistence of biodiversity and other natural features *in situ* (Watson et al. 2011).) This means that plans will necessarily use existing, purpose built (e.g. Marxan (Ball & Possingham 2000), C-Plan (Pressey et al. 2009) and Zonation (Lehtomäki & Moilanen 2013)) or other algorithmic (e.g. linear/non-linear programming, genetic algorithms) decision-support tools in the 'spatial prioritisation' stages (Stages 8 and 9 in Figure 2.1).

We acknowledge that not all organisations currently use computerised decision-support tools (beyond GIS alone) to identify priority areas when undertaking conservation planning. However, for the purposes of this systematic map, we have decided to focus only on plans which involve use of computerised decision-support tools, because broader definitions of systematic approaches to conservation planning are often vague, potentially referring to a wide variety of studies which would be difficult to consider as comparable interventions (see 'Comprehensiveness of search').

Table 2.1: Conservation planning definitions.

Conservation planning	The process of identifying, configuring and managing conservation resources and actions to protect biodiversity and ecosystem services.
Systematic approaches to planning	Planning stages approximate those in Figure 2.1, i.e. the setting of explicit conservation objectives, spatial biological data (typically multiple species and/or habitats), socioeconomic and other datasets, stakeholder consultation (Pressey et al. 2013) and ultimately, the identification of priority areas for the allocation of conservation resources. Core biological principles such as representation and persistence (adequacy; achieved by applying the principles of complementarity, irreplaceability, connectivity and related methods (Kukkala & Moilanen 2013)) are considered alongside non-biological considerations, including social and political constraints and opportunities (Naidoo et al. 2006; Ban et al. 2013). E.g. The planning process for California's Marine Life Protection Act in north central California, USA (Gleason et al. 2010).
Systematic conservation planning	In addition to including all above components: a) The benefits of conservation actions are specified either as threshold amounts of natural features to be represented or as continuous functions with increasing amounts of features; and b) the outputs are one or more optimal or near optimal sets of spatially-bounded conservation actions. Plans will necessarily use decision-support tools in the 'spatial prioritisation' stages. E.g. The Representative Areas Program for the rezoning of the Great Barrier Reef, Australia (Fernandes et al. 2005).

The discipline of systematic conservation planning has had a major influence on implementation strategies by international conservation organisations (Myers et al. 2000; Groves et al. 2002; Sanderson et al. 2002; Didier et al. 2009b; Morrison et al. 2009; Watson et al. 2011), guided policy decisions by government agencies (Finkel 1998; Fernandes et al. 2005) and resulted in thousands of academic publications (Kukkala & Moilanen 2013; Kullberg & Moilanen 2014). Despite the large increase in number of plans (Kukkala & Moilanen 2013) and resources spent on planning (a systematic conservation plan can cost millions of dollars and multiple years to develop (Pressey & Bottrill 2009)), the impact of this discipline on the effectiveness of spatial conservation initiatives is hypothesised but has not been rigorously tested. Preliminary analyses suggest the process of planning may sometimes be

more influential than the plan itself (Bottrill et al. 2012; Pressey et al. 2013) and that balancing a systematic science-based approach with the needs and aspirations of local people is essential (Henson et al. 2009; Knight et al. 2011b). Due to a lack of clear protocols for undertaking evaluations of conservation plans (Bottrill & Pressey 2012), there is no definitive review as to whether the technique has resulted in improved biodiversity conservation outcomes when compared with *ad hoc* decisions about the prioritisation of conservation actions. In fact, no comprehensive list exists of all the systematic conservation plans ever developed.

Published reviews of the effectiveness of conservation planning around the globe have been limited in scope, restricted to analyses of the peer-reviewed literature, pertaining to narrow time periods and have not always involved input from practitioners (Knight et al. 2008; Bottrill & Pressey 2012; Kullberg & Moilanen 2014). Attempts have been made to define effective conservation planning, which has led to an awareness that there are no universally applicable solutions and the greatest challenges are operational rather than technical (Knight et al. 2013; Raymond & Knight 2013). Without this information, conservation organisations and agencies have difficulty defending their actions to funders and stakeholders, plans may continue to be undertaken in situations where they may be an inefficient solution (Naidoo et al. 2006; Knight et al. 2011c), and conservation planners cannot discern which elements of the process are likely to be most influential. The number of localised evaluations and case studies of systematic conservation planning projects is indeed rising (Bottrill et al. 2011; Sisiolo 2013; Carter et al. 2014; Weeks et al. 2014), but their patchiness and lack of consistency provide the justification for undertaking a systematic mapping exercise to identify, characterise and assess the current state of knowledge in this area.

Conservation planners occasionally outline the outcomes they intend from plans, but rarely outline the causal chains they expect to lead to such outcomes. Common assumptions are that systematically derived plans: will identify more resource-efficient networks for biodiversity

conservation than other methods (Smith et al. 2006), will lead to improved governance and collaborations (Gelderblom et al. 2003; WWF European Alpine Programme 2005), capacity building (Gelderblom et al. 2003), trust and transparency (Smith et al. 2006; Cowling et al. 2008), can and will be implemented (Fernandes et al. 2005; WWF European Alpine Programme 2005) and, most importantly, will lead to better conservation outcomes than in the absence of systematic planning. Among the less explicitly stated assumptions are that: accuracy and rigour behind the biophysical inputs is of greatest importance (these are often given primacy over social, economic, cultural and feasibility considerations), and other organisations or government departments will take the plan into account when undertaking their own activities (WWF European Alpine Programme 2005). In a few examples, unexpected causal factors have been reported, such as the importance of public education prior to support for a plan (Fernandes et al. 2005). There may be complex interactions between socioeconomic and conservation outcomes (Oldekop et al. 2015), however, in general, the social and governance factors (Knight et al. 2013) which influence conservation decisions remain poorly understood (Ban et al. 2013).

To evaluate the true effects of conservation plans, a conceptual understanding of the possible outcomes (both intentional and unintentional) of conservation planning is required, extending beyond environmental outcomes to include social, political and financial considerations. A few early attempts to develop a conceptual model for systematic conservation planning exist. Kapos et al. (2008) proposed a generic conceptual model for research and conservation planning. However, we find this model too prescriptive and less suitable for this systematic mapping exercise given our limited understanding of causal pathways, specific mechanisms and feedback loops in conservation planning. Bottrill and Pressey (Bottrill & Pressey 2012) also proposed a preliminary results chain for conservation planning where impacts of plans are traceable through a series of inputs, processes or actions, outputs and short term outcomes.

However, we now interpret impacts as being able to arise at any point in the planning process, their measurement being subject to the robustness of the study design employed. Instead, our conceptual diagram (Figure 2.2) is simplified to focus on the types of possible outcomes currently assumed to result from systematic conservation planning exercises. In later analyses it may be possible to break down specific causal pathways unique to the systematic conservation planning process.

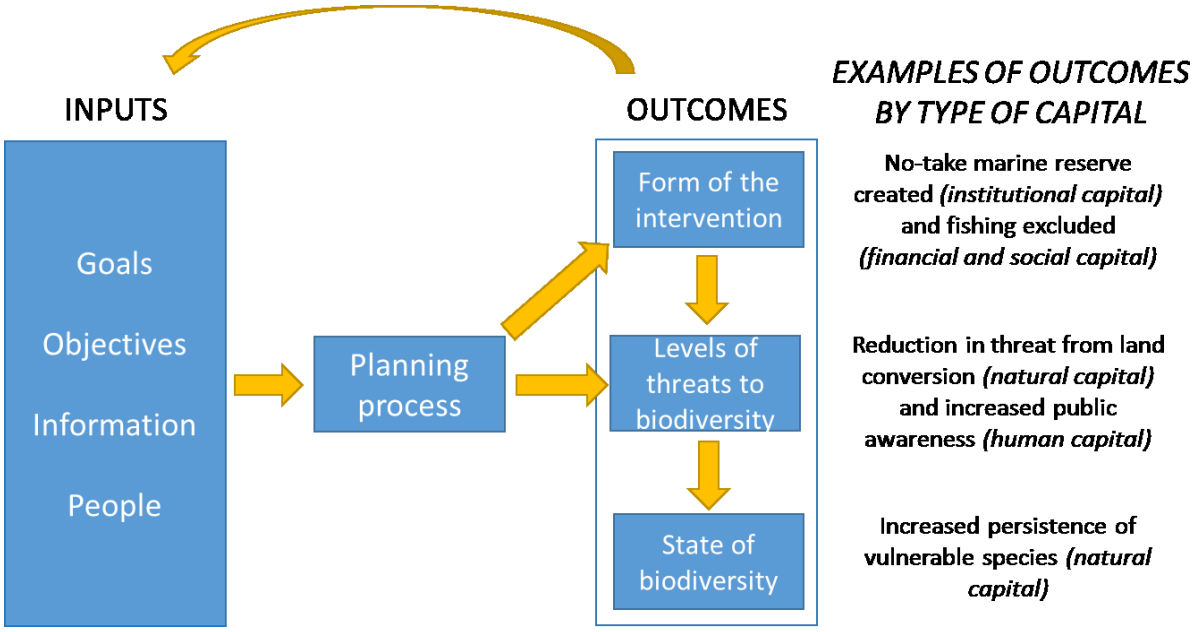

Figure 2.2: A conceptual model for systematic conservation planning. A range of inputs influence the planning process. The planning process often involves the integration of decision-support tools, stakeholder consultation exercises and iterative assessments of biological and other spatial datasets. Different types of outputs from the planning process will lead to different types of outcomes however, given the causal chains are not yet well understood, single arrows have been used to indicate the influence of the planning process on the types of potential outcomes. Immediate outcomes relate to the form of the intervention and longer term outcomes relate to threat levels and the state of biodiversity (see Pressey et al. (2015) for more on this pathway). Potential outcomes extend beyond just those to natural capital, also encompassing financial, social, human and institutional capital, as indicated in the examples. The feedback arrow from outcomes to inputs indicates the adaptive approach used to modify plans subject to observed outcomes.

This conceptual framework will be employed to a) understand the conceptual basis for the study and the types of outcomes of conservation planning, b) frame the data extraction

form/coding tool, particularly when identifying reported outcomes, and c) to aid in the analysis and presentation of results.

Objective of the map

This searching exercise will identify retrospective studies that measure the effects of systematic conservation planning exercises on biodiversity conservation at regional, national and sub-national scales (i.e. the scales at which conservation actions are undertaken) (Table 2.2). The systematic map will take the form of a searchable database, which will collate a body of literature and curate the evidence linking systematic conservation planning and biodiversity conservation outcomes. As such, it will focus specifically on evaluations of systematic conservation plans, rather than identifying a comprehensive list of all plans ever developed. By evaluations we refer to: systematics methods for collecting, analysing, and assessing information on the effectiveness of projects and policies in relation to stated goals (Patton 2008b), which can take multiple forms. It will exclude gap analyses and evaluations of non-spatial prioritisations, e.g. the triage of threatened species (Joseph et al. 2009).

Table 2.2: Key elements of the study research question.

Subject	Geographic region of conservation interest at regional, national and subnational scales. Inclusive of all countries and marine, freshwater, estuarine and terrestrial regions.
Intervention	Systematic conservation planning: a process for locating and implementing conservation actions.
Comparator	Comparisons over time (continuous or interrupted time series*), and/or between control and intervention groups and/or sites.
Outcome	Any reported change in the condition or state of natural, financial, social, human and institutional capital associated with the planning process.

*In an interrupted time series design data is collected at several time points before and after an intervention (Ramsay et al. 2003).

Our primary research question is: What is the extent and distribution of evidence on conservation outcomes of systematic conservation planning around the globe?

Here we define an outcome as a state or temporal change associated with a conservation planning process (that might or might not be directly attributable to a conservation plan), as distinct from an impact, which is the value added to a counterfactual estimate of a variable of conservation interest (Pressey et al. 2015). It is only possible to attribute apparent improvements or declines in biodiversity to a planning exercise (rather than other causes) through impact evaluation, which relates to the choice of an experimental or quasi-experimental design for the evaluation (Ferraro & Hanauer 2014) (this will be addressed through our categorisation of studies according to robustness of study design). A finding that no or few impact evaluations have been undertaken on systematic conservation plans would highlight an important gap in evaluations of the technique to date.

The evidence base will be examined and categorised using a data extraction framework designed to explore the following secondary questions:

- What are the characteristics of the current evidence base including information on study location, study scale and design, intervention type and outcome type?
- What types of outcomes of systematic conservation planning exercises are measured (either by the original planning organisation(s) or others)?
- What types of study designs are used in evaluations of systematic conservation planning?
- What is the level of robustness of existing evidence? How many impact evaluations have been conducted, where and by whom?

For our purposes we define outcomes according to the five types of capitals: natural, financial, social, human and institutional (Table 2.3), as proposed and defined by Bottrill and Pressey (2012). By reporting on a range of outcomes we are able to accommodate a diverse range of opinions on effectiveness, reflecting the different types of stakeholders involved in conservation planning.

Table 2.3: Potential outcomes of systematic conservation planning arranged according to capitals.

Categories adapted from the typology developed by Bottrill and Pressey (2012).

Capital	Definition	Outcome sub-category
Natural	The stock and flow of goods and services provided by ecosystems, including the diversity of species, regulating processes, and supporting services (Costanza et al. 1997).	Representation of biodiversity Reduction in loss or degradation of natural values Persistence of biodiversity Maintenance of ecosystem services
Financial	The gain or loss of cash, property or assets that represent the economic value of an individual or organisation.	Transparency in conservation investments Efficiency of operations Maximised benefit given limited budget Leverage of additional funds or in-kind support
Social	Represents the relationships and interactions between individuals and groups (Pretty & Ward 2001).	Collaboration among agencies Coordination between different actors Trust in planning process Sharing datasets between agencies Shared vision Attitudes of stakeholders Power dynamics between stakeholders
Human	Knowledge or skills that enable people to develop strategies to achieve their objectives (DfID 1999).	Raised awareness of biodiversity or conservation New knowledge of ecological or social values Learning applied in future plans
Institutional	Capacity, structure, or functioning of institutions through formal (e.g. laws) or informal means (e.g. local governance practices) (Platje 2008).	Influence on future decision making by organisation or partners Self-sustaining strategies Role of implementing agency Consideration of conservation issues in decision making by other sectors Integration of priorities into policies, conventions or legislation Influence on resource-use planning Protected areas expanded

Methods

Search terms

A search string, consisting of subject- intervention- and outcome-related keywords in English, will be used to query publication databases, search engines and online repositories.

Subject terms: TS=(aquatic OR "river basin" OR ecoregion* OR bioregion* OR terrestrial OR marine OR freshwater OR coastal OR landscape OR seascape OR catchment OR coastal zone OR "ecological network" OR corridor OR "conservation area" OR "reserve network" OR "protected area" OR metapopulation OR "national park" OR reserv* OR "priority area" OR "planning unit")

AND

Intervention terms: TS=("conservation plan*" OR "environmental plan*" OR "land use plan*" OR "spatial plan*" OR "conservation assessment" OR "reserve selection" OR "area selection" OR "reserve design*" OR "site selection" OR "conservation zoning" OR "key biodiversity area" OR "important bird area" OR "spatial priorit*" OR "conservation priorit*" OR "conservation area priorit*" OR "spatial optimi*" OR "conservation area selection" OR "protected area network design" OR "resource allocation" OR "conservation decision making" OR marxan OR zonation OR RobOff OR "C-plan" OR BioRap OR CLUZ OR ConsNet OR CPlan OR CPLEX OR CREDOS OR "Ecoseed Marzone" OR MinPatch OR MultCSync OR NatureServeVista OR ResNet OR SPEXAN OR "conservation evaluation" OR "area identification" OR "decision-support tool" OR "conservation action")

AND

Outcome terms: TS=(outcome* OR evaluat* OR output* OR impact* OR effect* OR ineffective OR success* OR fail* OR benefit* OR awareness OR behavi* OR implement* OR influen*)

This list of search terms was derived by reviewing titles, abstracts, keywords and terms used in similar papers e.g. (Knight et al. 2008; Bottrill & Pressey 2012; Kukkala & Moilanen 2013), and by looking up synonyms in the Oxford Thesaurus of English (Waite & Oxford University Press 2009). A scoping exercise in Web of Science (Thomson Reuters) was used to test the suitability and efficiency of alternate terms, wildcards and the use of standardised Boolean search conventions. The resultant search string was compared against a test library of eight publications (selected on the basis they were all the available studies which provide an example of an evaluation of one or more systematic conservation plan(s) which we were aware of) [see Appendix 2.1 for full list]. Search terms which did not retrieve many relevant articles were dropped from the list, as were terms which returned too many largely irrelevant results. To avoid the searches returning conservation interventions related to other disciplines e.g. art conservation, descriptors were included: TS=(biodivers* OR wildlife OR species OR habitat).

A detailed record of the evolution of the search string has been created to outline modifications to the initial search string made during the initial scoping exercise [Appendix 2.2]. The search string will be further refined during the full searches as necessary. Searches will be conducted in English only due to resource constraints. Publications returned in other languages will be recorded separately for potential follow-up in future (provided the titles and abstracts are also available in English).

Searches

This search strategy will aim to identify and classify English language studies in a systematic way, capturing both peer-reviewed and 'grey' literature, to ensure comprehensiveness, objectivity and reproducibility. Our search strategy was designed to favour sensitivity over specificity to avoid the likelihood of missing potentially important studies at the cost of extra time required to filter literature found. Input from experts and practitioners working in systematic conservation planning was sought in the design of this protocol to improve the

likelihood that the search strategy includes all relevant search terms and sources, and to ensure the final map will be of value to end users (Cook et al. 2013). Unless otherwise indicated, searches will be conducted for studies produced between 1983 and 2016, inclusive.

Publication database searches

Three peer-reviewed publication databases will be searched: Web of Science ™ Core Collection (Thomson Reuters) and SCOPUS (Elsevier) which cover the natural and social sciences, and CAB Abstracts (Centre for Agriculture and Biosciences International), which is specifically targeted to environment, resource management and agriculture.

The search string has been developed for Web of Science™ Core Collection and will be used to search that database by the field 'Topic', which includes title, abstract and keywords. A preliminary search returned 7,571 results (refining by subject did not appear to be necessary). The search string will be slightly modified to suit the individual requirements of SCOPUS and CAB Abstracts, which will both also be searched on the fields; title, abstract and keywords.

Search engine searches

The academic search engine Google Scholar (scholar.google.co.uk) has been demonstrated to be a valuable complement to traditional publication databases in systematic reviews in environmental disciplines, because it includes grey literature not found in the latter sources or by traditional grey literature search methods, thereby increasing the comprehensiveness of the overall search (Haddaway et al. 2015a). Haddaway et al. (2015a) found relatively little overlap between Google Scholar and Web of Science.

Google Scholar will be searched using a modified version of the publication database intervention search string in the advanced search option:

allintitle: "conservation plan" OR "conservation planning" OR "land use plan" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning" OR "conservation action"

The search string has been simplified because only basic Boolean logic is supported by Google Scholar, which accepts one 'OR' substring along with one additional term (that can be connected with 'AND' to the OR-substring). Searches will be conducted on title only.

When using Google Scholar to look for grey literature, searching on title only has been found to be more efficient than searching all text (Haddaway et al. 2015a). Only the first 1,000 results will be retrieved as this is the total number of viewable search results due to the limitations of Google Scholar. During a preliminary search in May 2016, 7,710 results were retrieved so approximately a seventh of the potentially relevant publications will be assessed. Evaluations of plans are no more likely to appear in the first 1,000 results than the remainder. Therefore, to increase the likelihood of finding evaluations using Google Scholar, an additional search will be conducted with the search criteria modified so that 'evaluation' must appear in the title (this returned 93 results in the trial). Web scraping tools (Import.io Ltd.) will be used to download and extract citation data for Google Scholar search results.

Other online repositories

A grey literature repository of government literature, Open Grey (http://www.opengrey.eu/) PAIS International (ProQuest) and databases of conference proceedings: Proceedings First and Papers First (OCLC Online Computer Library Center, Inc.) will also be searched by title only (due to the large number of references obtainable) for the period 1983 to 2016 (1993 to 2016 for Proceedings First and Papers First due to the availability of OCLC records).

Other web search engines such as Google, WISER, deep web search tools and online thesis databases will not be searched due to time constraints and because the inclusion of academic search engines and targeted searches of organisational websites is expected to be more efficient.

Targeted searches

Targeted searches will be conducted with the primary aim of identifying and locating grey literature publications from both unpublished sources and organisational databases. This distinction between 'file drawer' and ‘practitioner-generated research' will ensure more efficient grey literature searching (Haddaway & Bayliss 2015). Three approaches will be used: systematic searches of the databases and websites of key organisations involved in conservation planning, subject expert consultation and opportunistic identification of studies.

The selected organisational databases and websites have been chosen on the basis of having an international presence in conservation planning and for the potential to hold records of large numbers of such projects. The list (Table 2.4) was derived through consultation with conservation planning experts, and organisations which were mentioned frequently in the literature.

Table 2.4: Websites of specialist organisations and online databases.

Organisation/Organisational database	Website
Campbell Collaboration	www.campbellcollaboration.org /lib/
Center for International Forestry Research (CIFOR)	www.cifor.org
Collaboration for Environmental Evidence	www.environmentalevidence.org
Conservation Evidence	www.conservationevidence.com
Coral Triangle Initiative	www.coraltriangleinitiative.org
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia	www.csiro.au
Evidence on Demand	http://www.evidenceondemand.info/library.aspx
IUCN Evaluations database	www.iucn.org/knowledge/monitoring_evaluation/database/all_iucn_evaluations
IUCN World Commission on Protected Areas	www.iucn.org/about/work/programmes/gpap_home/gpap_wcpa
Natureserve	www.natureserve.org
OECD iLibrary	www.oecd-ilibrary.org
Poverty and Conservation Learning Group	povertyandconservation.info
Protected Planet	www.protectedplanet.net
SANBI Planning database, South Africa	www.sanbi.org
The Digital Observatory for Protected Areas (Europe)	dopa.jrc.ec.europa.eu
The Nature Conservancy – Conservation Gateway	www.conservationgateway.org/ConservationPlanning/Pages/conservation-planning.aspx
United Nations Environment Programme – World Conservation Monitoring Centre	http://www.unep-wcmc.org
USAID	www.usaid.gov/biodiversity
Wildlife Conservation Society	www.wcs.org
World Bank	web.worldbank.org
World Wildlife Fund for Nature International	wwf.panda.org
Critical Ecosystem Partnership Fund	www.cepf.net

Where possible, organisational databases and websites will be searched on all text using the Google Scholar search string. Where database or within-website searching is not possible, citation metadata for all publications available on a given website or database will be collated.

The second type of targeted searching - subject expert consultation - will involve a select group of subject experts, who will be approached to provide suggestions of publications, organisational websites and databases we may not have considered. Subject experts will be

selected to represent prominent conservation planners in the NGO, academic and government sectors. Ongoing reviews and related initiatives will be examined as appropriate.

Promotion of this study and requests for relevant publications have been made opportunistically, including at a major international conference (the 27th International Congress for Conservation Biology, Montpellier, August 2015) to increase the chances of identifying additional difficult-to-access publications.

In all cases, potentially relevant publications not found through previous search strategies will be added to the reference list. We will also conduct forwards and backwards bibliographic searches of citations for all publications in the test library [Appendix 2.1], seminal reviews of conservation planning (Margules & Pressey 2000; Sarkar et al. 2006; Grantham et al. 2010; Bottrill & Pressey 2012; Kukkala & Moilanen 2013), and relevant articles included in the map database.

Comprehensiveness of search

Our search strategy is largely focused on peer-reviewed publications from 1983 onwards. The first systematic conservation plans appeared in the published literature in that year (Kirkpatrick & Harwood 1983; Pressey 2002). A limitation to the comprehensiveness of the search will be document availability (e.g. the chosen conference abstract databases are not searchable prior to 1993) and the inclusion of only English language publications due to time and resource constraints. Access to grey literature is another limitation. However, incorporating multiple approaches to identifying and locate grey literature will help to address this constraint. A subset of key websites and databases have been selected rather than all potentially useful websites for practicality reasons.

Our decision to exclude systematic approaches which do not involve the use of computerised decision-support tools may result in the final suite of included studies being associated with

well-resourced nations or projects only. In order to explore this potential geographic trend, during the screening process we will record those studies which exhibit many of the characteristics of a systematic conservation plan, but which are excluded on the basis they do not involve the use of computerised decision-support tools (according to Table 2.1). Following the completion of the systematic map, we will then map those excluded, non-computational systematic studies geographically to determine if there is a difference in the locations of such studies compared with those which meet our systematic conservation planning criteria. If there are far too many excluded systematic studies to map every one, we will randomly subsample those to obtain a better understanding of potential trends.

To ensure suitability of the search string, and to maximise the comprehensiveness of the resultant searches, alternate subject and intervention terms have been refined with reference to the test library (Appendix 2.1) and enhanced by the inclusion of synonyms and wildcards. If initial searches do not return all publications in the test library, the search string and search strategy will be refined until all publications are returned. Primary studies will be included rather than secondary reviews. However, when review papers are found, they will be used to identify related primary studies.

Article screening and inclusion criteria

Screening process

The web scraping software Import.io (Import.io Ltd.) will be used to extract publication metadata (e.g. publication titles, authors, publication date etc.) to increase automation and efficiency. Once the search strategy has been completed, all results obtained will be entered into the software EPPI-Reviewer (V.4.5.1.0, (Thomas et al. 2010)) and duplications will be removed to create the main reference list. EPPI-Reviewer will be used to coordinate screening and data extraction.

For records obtained from web scrapes of organisational websites, preliminary screening will then be conducted within EPPI-Reviewer, using the Google Scholar search string (searching on all text because grey literature publications are expected to have more general titles and potentially lack abstracts) and only relevant articles will be included in further screening.

The approach to screening will be standardised across all publications regardless of source. Initially all publication titles will be reviewed in accordance with the inclusion and exclusion criteria by the primary researcher. Given the large number of articles expected, if it appears necessary to screen more than 8,000 studies at the title screening stage (a realistic number for one reviewer), an additional reviewer will be involved. In this instance, and at each stage (title only, title and abstract, and full text) during the piloting of the screening process, a random sample 10%, or 50 articles (whichever is greater) will be selected for a kappa analysis to determine whether the two reviewers/raters are applying the inclusion criteria consistently. The Online Kappa Calculator (Randolph 2008) will be used to measure the chance-adjusted measure of agreement between the two raters and values of lower than 0.70 will trigger discussions about the reviewers' approaches followed by additional pilot screening until the kappa scores are over 0.70 at each screening stage. Should the two reviewers have different views on the application of part of the inclusion criteria, all authors and reviewers will reach a consensus decision about the preferred approach.

For retained articles following title screening, all abstracts will be obtained and entered into EPPI-Reviewer if not already obtained. Titles and abstracts will then be manually screened in accordance with the inclusion and exclusion criteria. Retained articles at this stage will go on to full text screening, as outlined in the following sections. At the completion of full text screening, a list of excluded articles will be produced, including reasons for their exclusion.

After search results have been compiled the studies will be screened against a set of inclusion criteria:

Relevant subject

Studies relating to plans developed at regional, national and subnational scales (the scales at which conservation actions are operational, rather than studies which evaluate global scale plans such as Conservation International's Biodiversity Hotspots (Myers et al. 2000)). Inclusive of all countries and marine, freshwater and terrestrial realms. Studies published between 1983 and 2016.

Relevant intervention

Systematic conservation planning (Margules & Pressey 2000): a process for locating and implementing conservation actions where: a) the benefits of conservation actions are specified either as threshold amounts of natural features to be represented or as continuous functions with increasing amounts of features; and b) the outputs are one or more optimal or near optimal sets of spatially-bounded conservation actions. This means that plans will necessarily use existing (e.g. Marxan (Ball & Possingham 2000), C-Plan (Pressey et al. 2009) and Zonation (Lehtomäki & Moilanen 2013)) or custom-made (e.g. linear/non-linear programming, genetic algorithms) decision-support tools in the 'spatial prioritisation' stages. Studies which relate to plans that have no explicitly stated biological conservation objectives, or studies which relate to plans that were solely expert-based approaches (which are not repeatable and are less defensible and transparent (Knight et al. 2008)) will be excluded.

Relevant outcome

Studies which measure changes in the condition of one or more of the following forms of capitals: natural, financial, social, human and institutional (either quantitatively or qualitatively). We will take a broad interpretation of outcomes in order to capture the breadth of intended and unintended outcomes and potential flow-on consequences for biodiversity conservation.

Relevant comparator

Comparisons over time (continuous or interrupted time series), and/or between control and intervention groups and/or sites. Studies which measure a single point in time, with no comparison to another site will be excluded.

Relevant study design

Retrospective quantitative and qualitative experimental, quasi-experimental and non-experimental designs according to Margoluis et al. (2009). Theoretical studies, prospective models, or studies which only use ex-post modelling to estimate business as usual versus future planning scenarios will be excluded, as will studies based on researcher inference, however these will be quantified as we expect these to be common.

If there is any doubt about the relevance of a study at any screening stage, it will be included for evaluation in the subsequent screening round to avoid removing potentially relevant studies. Where a publication meets our criteria for being a systematic conservation plan but does not meet our criteria for being an evaluation, the record will be marked as such and kept aside, as these records will potentially be informative for other efforts to collate a comprehensive database of conservation plans worldwide.

Study quality assessment

Information about the study design of relevant articles will be recorded to determine study robustness, in light of a full critical appraisal (James et al. 2016). Studies will be coded as experimental, quasi-experimental, non-experimental, involving qualitative sampling or 'other' according to Margoluis et al.'s categorisation of quantitative and qualitative study designs (Margoluis et al. 2009), similar to that used by Bottrill et al. (2014) in this journal [Appendix 2.3]. This will provide an overview of the type of data collected and methods used, to guide

more detailed data extraction and assessment of evaluation methodologies used, in a future systematic review.

Data coding strategy

The final list of relevant articles (those included following full-text screening) will be examined and data recorded based on a standardised coding tool [Appendix 2.3]. The coding tool was developed based on similar studies (Garcia-Yi et al. 2014; Bottrill et al. 2014) with the aim of recording descriptive information about the study in relation to our research questions. EPPI-Reviewer will be used to standardise and streamline data coding as each publication is assessed.

The following main categories of data will be extracted:

- bibliographic information
- basic information about the conservation planning process in question
- information about the study design
- types of outcomes reported.

Existing typologies have been chosen where available (e.g. for IUCN categories of conservation actions (Salafsky et al. 2008), see Appendix 2.3). The selected typology of outcomes is based on the capitals framework (natural, financial, social, human and institutional) proposed by Bottrill and Pressey (2012) (Table 2.2). Subcategories of outcomes will be revised based on coding results from relevant studies.

Systematic conservation plans can be developed for a range of reasons, exhibit different characteristics and potentially lead to different types of outcomes. Hence a typology of interventions (types of plans), will be used to categorise studies, broadly broken down into those plans which were a) developed by the end user(s) for *direct application*, such as a government seeking to acquire land to create or expand a protected area network, b) were used

to *identify priority conservation actions* and the optimal spatial and temporal allocation of these, in order to influence decisions taken by other organisations, or c) used to *retrospectively evaluate* or examine the efficiency and suitability of an existing protected area network. This typology will be refined as necessary given no existing typology exists to categorise types of systematic conservation plans.

An additional suite of in-depth questions have been posed in the event the final list of studies is small enough to warrant a second, more detailed round of data extraction, relating to reported characteristics such as: causal mechanisms associated with reported outcomes, the purpose of the study, cost of the planning process and context of the plan [Appendix 2.3].

To ensure repeatability of data coding, each reviewer will select a subsample of at least ten coded articles during the early stages of data coding, to check for consistency in their choice of codes and to reconcile any differences in selection. If necessary, they will amend the codes in discussion with the other reviewer before coding the remainder of the articles. To verify the consistency and repeatability of data coding and the study quality assessments between the two reviewers, a random sample of 10%, or 50 articles (whichever is greater) will be selected for kappa analysis. We will also assess intercoder reliability (Lombard et al. 2002) through the application of Krippendorff's alpha index (Krippendorff 1980), a more flexible measure. The choice of codes of the two reviewers will be compared and harmonised as necessary and the results of the intercoder reliability assessments will be reported.

Study mapping and presentation

We will present the results in a publication (to be published in this journal) as well as an open-access, searchable database of studies and related coding results, available to be updated in future. In addition, a visual overview of available evidence will be developed (in the form of a structured matrix) in order to share our findings with practitioners, policy makers and

researchers in a summarised and engaging way. This matrix will show how the interventions (different types of systematic conservation plans/rows) relate to different outcomes (columns) [Appendix 2.4] to highlight areas where little or no evidence exists, and the robustness of the evidence based on study design. Within each cell any relevant studies will be listed (and associated article(s)), colour coded by study design, to convey the amount and robustness of evidence available for each type of outcome. Any associated outcome patterns will also be reported, for example, which combinations of outcomes are most often reported together. In order to identify potential patterns of interest, results will be presented according to the frequency of studies by country, biome, and publication type. A geographic map of the location of each included study will be compiled and if sufficient studies report on the causal mechanisms associated with reported outcomes, these will be presented also. We will explore methods of displaying the structured matrix as an interactive online tool, similar to the approach developed by the International Impact Initiative (3ie) (gapmaps.3ieimpact.org).

Abbreviations

IUCN: International Union for Conservation of Nature

Availability of data and materials

Machine-readable files e.g. spreadsheets, will be provided as supplementary material with the systematic map when it is submitted for publication in *Environment Evidence* and are expected to be downloadable from the *Environmental Evidence* website.

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3

Paper 3: Online tools supporting the conduct and reporting of systematic reviews and systematic maps: a case study on CADIMA and review of existing tools

The published article is available online:

Kohl C*, McIntosh EJ*, Unger S*, Haddaway N, Kecke S, Schiemann J, Wilhelm R. 2018. Online tools supporting the conduct and reporting of systematic reviews and systematic maps: a case study on CADIMA and review of existing tools. Environmental Evidence 7:e1-17. Doi: 10.1186/s13750-018-0115-5 * These authors contributed equally to this work.

This text reflects the accepted manuscript but may not include minor editorial changes made prior to publication.

Abstract

Systematic reviews and systematic maps represent powerful tools to identify, collect, evaluate and summarise primary research pertinent to a specific research question or topic in a highly standardised and reproducible manner. Even though they are seen as the "gold standard" when synthesising primary research, systematic reviews and maps are typically resource-intensive and complex activities. Thus, managing the conduct and reporting of such reviews can become a time consuming and challenging task. This paper introduces the open access online tool CADIMA, which was developed through a collaboration between the Julius Kühn-Institut and the Collaboration for Environmental Evidence, in order to increase the efficiency of the evidence synthesis process and facilitate reporting of all activities to maximise methodological rigour. Furthermore, we analyse how CADIMA compares with other available tools by providing a comprehensive summary of existing software designed for the purposes of systematic review management. We show that CADIMA is the only available open access tool that is designed to: 1) assist throughout the systematic review/map process; 2) be suited to reviews broader than medical sciences; 3) allow for offline data extraction; and, 4) support working as a review team.

Keywords

Review management, managing systems, systematic review software, evidence synthesis, time management, rapid review, text mining

Background

Systematic reviews were first established in the field of healthcare to support evidence-based decision making (Guyatt 1992). Their use is continuously expanding into other disciplines, including social welfare, international development, education, crime and justice, environmental management (including the impact assessment of crop genetic improvement technologies (Kohl et al. 2013, 2015; The European Commission 2013)), software engineering (Kitchenham & Charters 2007) and food/feed safety assessment (European Food Safety Authority 2010). Systematic reviews and related systematic maps follow standardised and rigorous methodologies aiming to ensure comprehensiveness, minimise bias, and increase transparency (CEE 2013; James et al. 2016). Although seen as a "gold standard" when synthesising primary research, the central tenets of systematic review and map methodologies necessarily increase the complexity of the review processes and their resource requirements (i.e. time, money and personnel).

In order to support reviewers throughout the conduct of their syntheses, and to increase efficiency and maximise methodological rigour, software tools have been developed by a diverse set of providers to support review teams during the evidence synthesis process (the term evidence synthesis is used herein to cover both systematic reviews and systematic maps, which aim to characterise the available evidence-base rather than providing quantitative or qualitative answers to an impact or effectiveness question (Bragge et al. 2011; James et al. 2016)).

Potential drawbacks associated with these tools include that: 1) they may not be open access (i.e. free to use, an important consideration for non-profit organisations in particular); 2) they may be targeted to a particular research discipline, meaning that their applicability in other disciplines may be restricted; 3) they may not support the entire evidence synthesis process; and, 4) they may have been developed solely for systematic reviews and may not support the conduct of systematic maps.

Here, we present the open access online tool CADIMA that was established by Julius Kühn-Institut (JKI) during a recently completed EU-funded project called GRACE (GMO Risk Assessment and Communication of Evidence). The project's working agenda included: 1) the conduct of a number of systematic reviews and maps for the purposes of increasing the transparency and traceability of information on potential risks and benefits associated with the deliberate release of genetically modified crops (Garcia-Yi et al. 2014; Gathmann & Priesnitz 2014a, 2014b, Kostov et al. 2014a, 2014b; Meissle et al. 2014; Sweet & Kostov 2014; Priesnitz et al. 2016); and, 2) the development of an open access online tool (CADIMA) to facilitate the conduct of systematic reviews and maps on agricultural and environmental questions. Due to the expertise available at the Collaboration for Environmental Evidence (CEE) and the overlap of topics covered by both institutions, a close collaboration between JKI and CEE was established to develop CADIMA.

Herein, we discuss how CADIMA compares with other available tools by providing a comprehensive summary of existing review management software, and also discuss possible future development of CADIMA. Existing reviews of available software and tools (e.g. Marshall et al. 2015), have quickly become out of date since many new software packages have been recently released or are in development. In order to ensure the independence of the review reported in this manuscript and the assessment of how CADIMA compares to existing tools, the review part of this paper was solely conducted by EJM as she was/is not involved in the development of CADIMA.

Methods

Review of existing online tools

A series of searches was conducted for the purposes of comparing CADIMA with other available online tools to identify software packages designed to facilitate evidence synthesis. We excluded software that only supported isolated aspects of, rather than the majority of, the systematic review process (e.g. reference management in Endnote, duplicate checking using the Systematic Review

Accelerator (Rathbone et al. 2015a; CREBP 2017), screening in Abstrackr (Wallace et al. 2012), meta-analysis in Comprehensive Meta-Analysis (CMA), or data extraction and quantitative synthesis in RobotReviewer (Marshall et al. 2016)). For more details on these and other tools, see the SR Toolbox: http://systematicreviewtools.com/.

The search strategy involved four approaches: 1) conducting online bibliographic database searches; 2) snowballing via general web searches (tracking backwards and forwards for studies via links in relevant websites); 3) screening targeted websites; and, 4) backwards and forwards citation searches of relevant publications (search methods are outlined in Appendix 3.1).

Following the completion of the searches, 24 systematic review software packages were identified from across a wide range of disciplines (Table 3.1). Of these, two were excluded from the analysis; one has been discontinued (Slrtool (Barn et al. 2014)), and the developers of another product currently in development, DRAGON ONLINE (https://www.icf.com/solutions-and-apps/dragon-online-tool-systematic-review), did not respond to our request for further information.

Table 3.1: Comparison of the functionality of currently available systematic review management software packages.

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
CADIMA ("CADIMA" 2017)	JKI - Julius Kühn-Institut	https://www.cadima.info/index.php/area/evidenceSynthesisDatabase	"CADIMA supports the conduct of systematic reviews and evidence/systematic maps by the provision of a freely available online tool."	Any, particularly suitable for *Environmental Evidence* systematic maps and reviews.	Development team is available to provide support or software modifications.	Qu, Pi, Du, Sc, Co, Cr, Do	Yes	No	Yes (at data coding stage)	Yes	Text mining capabilities in development	No	Free
Colandr (Cheng et al. 2018)	Conservation International	www.colandrapp.com	"computer-assisted systematic mapping software for evidence synthesis"	Any, particularly suitable for environment and development sectors.	Colandr Community website, videos, documentation.	Pi, Se, Du, Sc, Co, Sy, Do	Yes	No	No	Yes	Machine learning approaches to assist with article screening and data extraction.	Yes	Free
Covidence ("Covidence systematic review software" n.d.)	Covidence is a non-profit organisation	https://www.covidence.org/	"Covidence is a not-for-profit service working in partnership with Cochrane to improve the production and use of systematic reviews for health and wellbeing."	Healthcare & medical science, designed for Cochrane reviews.	Detailed help documentation and demonstration videos. Contact support available.	Du, Sc, Co, Cr	Yes	No	No	Yes	No	No	Range of packages e.g. 'Single': $240 USD per year, one review, unlimited reviewers.

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
DistillerSR (" DistillerSR" n.d.)	Privately held, Evidence Partners	https://www.evidencepartners.com/products/distillersr-systematic-review-software/	"DistillerSR is the world's most used systematic review software. It was designed from the ground up to give you a better review experience, faster project completion and transparent, audit-ready results."	Any	8X5 live technical support and detailed user manual with explanatory videos. Support for international character sets.	Se (PubMed), Du, Sc, Co, Sy, Do	Yes	No	No	Yes	In develoment. Currently supports keyword highlighting	No	Range of packages e.g. Student FREE: USD$0 and 'Faculty': USD$75 per month.
Early Review Organizing Software (EROS) (Glujovsky et al. 2011)	Institute of Clinical Effectiveness and Health Policy	http://eros-systematic-review.org/rev-login.php	"EROS is a new web-based software designed specifically to perform the first stages of a systematic review."	Healthcare & medical science	Email support and a user guide	Sc, Co, Cr	Yes	No	No	Yes	No	No	A donation for development (USD 600 per year for a team of up to 4 reviewers) is requested for non-Cochrane reviews (Cochrane reviews can use Covidence for free).
EPPI-Reviewer 4 (Thomas et al. 2010)	EPPI-Centre	http://eppi.ioe.ac.uk/CMS/Default.aspx?alias=eppi.ioe.ac.uk/cms/er4&	"EPPI-Reviewer 4 is a multi-user web-based application for managing and analyzing data for use in research synthesis."	Any	Detailed user manual and developers are available with advice and to make modification where possible.	Se, Du, Sc, Co, Cr, Sy, Do	Yes	No	No	Yes	Text mining to assist with identifying relevant studies.	No	User fee £10 per user per month, plus shareable review fee £35 per month.

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
Health Assessment Workspace Collaborative (HAWC) ("HAWC: Health Assessment Workplace Collaborative " 2013; Shapiro & Rusyn 2014)	Collaborative initiative	https://hawcproject.org/	"HAWC is a modular, content management system designed to store, display, and synthesise multiple data sources for the purpose of producing human health assessments of chemicals. "	Healthcare & medical science	Online documentation http://hawc.readthedocs.io/en/latest/ and Github repository. Requires knowledge of Python to run and to interpret help documentation.	Se, Sc, Co, Cr, Sy, Do	Yes	No	No	Yes	Unclear	Yes	Free
METAGEAR package for R (Lajeunesse 2015)	Marc J. Lajeunesse	http://lajeunesse.myweb.usf.edu/metagear/metagear_basic_vignette.html#introduction	"The metagear package for R contains tools for facilitating systematic reviews, data extraction, and meta-analyses."	Any	Online documentation and the developer is available for questions. Requires knowledge of R in order to run the software although there is a GUI interface for abstract screening.	Sc, Co, Sy	No	Yes	Yes, package operates offline	Yes	"PDF downloader to automate the retrieval of journal articles from online data bases; automated data extractions from scatter-plots, box-plots and bar-plots"	Yes	Free

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
PARSIFAL	Parsifal is a non-profit organisation	https://parsif.al/	"Parsifal is an online tool designed to support researchers to perform systematic literature reviews within the context of Software Engineering."	Software engineering	FAQs, online videos, Github repository (https://github.com/vitorfs/parsifal) and email support available.	Pi, Se, Du, Sc, Co, Sy	Yes	No	No	Yes	No	Yes	Free
Rayyan (Ouzzani et al. 2016)	Qatar Computing Research Institute	https://rayyan.qcri.org	"Authors create systematic reviews, collaborate on them, maintain them over time and get suggestions for article inclusion."	Any, close alignment with Cochrane reviews.	Online forum.	Pi, Se, Du, Sc	Yes	No	Yes, using a mobile app	Yes	The support vector machine classifier learns from users' decisions about including and excluding studies and scores unclassified studies for likely relevance. Similarity graph function for exploring citation networks.	No	Free
REviewER	Empirical Software Engineering Group	https://sites.google.com/site/eseportal/tools/reviewer	"REviewER aims at assisting researchers in the laborious process of conduction of systematic reviews."	Any, particularly software engineering.	GitHub repository (https://github.com/bfsc/reviewer). No user guide. Advanced coding skills required.	Qu, Pi, Se, Du, Sc	No	Yes	Yes, package operates offline	Yes	No	Yes	Free

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
RevMan 5 ("Review Manager (RevMan) Version 5.3" 2014) (this software is no longer being developed)	Cochrane Community	http://community.cochrane.org/tools/review-production-tools/revman-5	"Review Manager 5 (RevMan 5) is the software used for preparing and maintaining Cochrane Reviews."	Healthcare & medical science, designed for Cochrane reviews.	Online documentation. RevMan 5 support accounts are only available to registered Cochrane authors.	Pi, Sc, Co, Cr, Sy, Do d	No	Yes	Yes, package operates offline	Yes (cannot edit simultaneously)	No	No	RevMan 5 is free for Cochrane Reviewers or purely academic use. Commercial users require a license.
RevMan Web (will be available for beta-testing in 2017, replacing RevMan 5)	Cochrane Community	http://community.cochrane.org/tools/review-production-tools/revman-web	"RevMan Web is a new, web-based platform for preparing and maintaining Cochrane Reviews."	Healthcare & medical science, designed for Cochrane reviews.	RevMan Web will integrate with several other Cochrane software packages.	Pi, Cr, Sy, Do	Yes	No	Unclear	Unclear	Unclear	Unclear	Unclear
SESRA (Supporting Systematic Literature Reviews in Software Engineering) (Molléri & Benitti 2013)	UNIVALI - Universidade do Vale do Itajaí	http://sesra.net/	"Collaborative research, automated searches, online reference management, support to all the process phases and activities."	Any, particularly designed for software engineering	User guide and introductory videos available in Portuguese only.	Qu, Pi, Sc, Co, Sy, Do	Yes	No	No	Yes	No	Proposed in future	Free

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
SLR-Tool (Fernández-Sáez et al. 2010)	ALARCOS Research Group	http://alarcos.esi.uclm.es/slrtool/	"...a free tool... to be used by researchers from any discipline, and not only Software Engineering."	Any, particularly designed for software engineering	Unclear	Qu, Pi, Du, Sc, Co, Cr, Do	No	Yes	Yes, package operates offline	No	Yes, for example "...to cluster the documents by using the similarities among them, highlighting key words that identify each group of documents."	No	Free
SLuRp (Systematic Literature unified Review program) (Bowes et al. 2012)	See authors	https://codefeedback.cs.herts.ac.uk/SLuRp/	"...to support the complex task of managing large numbers of papers, sharing tasks amongst a research team and following the arduous and rigorous SLR methodology recommended by Kitchenham and Charters."	Software engineering	No user guide, minimal support information on product website. Requires use of MySql and Tomcat to run.	Se, Sc, Co, Cr, Sy, Do	Partially	Unclear	Unclear	Yes	No	Yes	Free

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
SRDB.PRO – Systematic Review Intelligence Platform	Privately held	https://www.srdb.pro/default	"...the first, enterprise level Business Intelligence platform designed specifically to improve the way in which the pharmaceutical industry and healthcare consultancies conduct systematic reviews and data analysis."	Healthcare & medical science, targeting the pharmaceutical industry and healthcare consultancies.	User guide. Phone and email support.	Se (PubMed), Du, Sc, Co, Cr, Sy, Do	No	Yes	Yes, package operates offline	Yes	No	No	SRDB.PRO Hosted is free for non-commercial use and starts at £70/ USD$119 per month for 1 active user. SRDB.PRO Enterprise is more expensive.
SRDR (Systematic Review Data Repository)	Brown Evidence-based Practice Center	http://srdr.ahrq.gov/	"...a Web-based tool for data extraction and storage of systematic review data."	Healthcare & medical science	User manual, FAQs and training videos.	Se, Co, Sy	Yes	No	No	Yes	No	No	Free
StArt (State of the Art through Systematic Review) (Fabbri et al. 2016)	Laboratory of Research on Software Engineering (LaPES)	http://lapes.dc.ufscar.br/tools/start_tool	"...aims to help the researcher, giving support to the application of this technique [systematic review]"	Software engineering	The online StArt community provides a forum, tutorials and videos.	Pi, Du, Sc, Co, Cr, Sy, Do	No	Yes	Yes, package operates offline	No	Yes, calculates scores of likely relevance of articles and similarity between articles.	No	Free

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
SUMARI (System for the Unified Management, Assessment and Review of Information). (designed to replace JBI CReMS software)	Joanna Briggs Institute (JBI)	https://www.jbisumari.org/	"SUMARI supports 10 review types, including reviews of effectiveness, qualitative research, economic evaluations, prevalence/incidence, aetiology/risk, mixed methods, umbrella/overviews, text/opinion, diagnostic test accuracy and scoping reviews."	Healthcare & medical science, also social sciences and humanities	FAQs and video tutorials	Se, Sc (full text only), Co, Cr, Sy, Do	Yes	No	No	Yes	No	No	Limited access beyond JBI special users initially. Subscriptions will be made available via Wolters Kluwer.
SWIFT-Review (Sciome Workbench for Interactive computer-Facilitated Text-mining) (Howard et al. 2016)	Privately held, Sciome	https://www.sciome.com/swift-review/	"a freely available interactive workbench which provides numerous tools to assist with problem formulation and literature prioritisation."	Healthcare & medical science	Tutorial and user guide	Se (PubMed), Sc (works in concert with SWIFT-ACTIVE Screener), Co, Sy, Do	No	Yes	Yes, package operates offline	Yes	Yes, the "software utilises recently developed statistical modeling and machine learning methods that allow users to identify over-represented topics within the literature corpus and to rank-order titles and abstracts for manual screening."	No	Free

Software name & reference	Ownership	Website	Description [a]	Intended field(s) of research	Available support	Stages of the SR process supported [b]	Web - Online	Can be downloaded	Supports offline working	Supports team of reviewers	Text mining features	Open source	Cost [c]
SyRF ("Systematic Review & Meta-Analysis Facility (Syrf)" 2017)	CAMARADES & NC3Rs	http://syrf.org.uk/	"SyRF is a fully integrated online platform for performing systematic reviews of preclinical studies."	Preclinical studies e.g. experimental animal studies	Online contact form, online tutorials available on request. User guide, video tutorial and in app tutorials in development.	Qu, Pi, Se (PubMed), Sc, Co, Cr, Sy	Yes	No (under development)	No (offline app under development)	Yes	Risk of bias items can be automatically extracted and machine learning is available to aid the screening process for English articles.	No	Free

[a] Descriptions taken from product websites, referenced documentation or through direct email contact with developers (where necessary).

[b] Stages of a systematic review: **Qu**: Setting up the review, with question formulation and/or stakeholder engagement; **Pi**: Scoping/pilot study, protocol development (e.g. PICO elements specified); **Se**: Literature searching (e.g. via integration with publication databases). Excludes those which require search results to be manually uploaded; **Du**: Duplicate checking (e.g. automated marking of duplicates, or identification of potential duplicates for manual checking); **Sc**: Article screening/study selection; **Co**: Facilitates data coding/tagging and extraction to support meta-analyses; **Cr**: Critical appraisal/risk of bias assessments; **Sy**: Facilitates quantitative/qualitative syntheses of results; **Do**: Generation of documentation/output of text, figures or tables to assist with report writing.

[c] Costs taken from respective websites, correct as of 02/11/2017. EROS cost estimates were provided by email (Gabriela Rodriguez, 07/04/17).

The 22 remaining software packages were researched and trialled by EJM (where free access or free trials were available) and characterised according to a suite of features, including; the stages of the systematic review process supported, whether they are suitable for a team of reviewers, and their cost (Table 3.1). These features were chosen in part based on previous studies on user preferences for systematic review software functionality (Marshall et al. 2015; Hassler et al. 2016). Developers were contacted when insufficient information was available online or in publications about a software package. Where no further information was available, the characteristic was marked as 'unclear'.

Introduction to CADIMA

CADIMA is a client-server software application and was developed by using the interactive management framework Scrum (http://www.scrumguides.org/) and the project management tool Redmine (http://www.redmine.org/). The user interface of the CADIMA web application requires a web browser, such as Mozilla Firefox or Google Chrome. CADIMA is coded with the programming language PHP V5.5 using the Yii V1.1 framework with the Bootstrap CSS extension (http://yiibooster.clevertech.biz/). The application runs on an Apache 2.4 web server and a Linux Ubuntu Server V14.04, and data are stored in a MySQL 5.5 database management system with a daily data backup stored for six months. CADIMA is permanently hosted and maintained by JKI and uses an SSL encrypted connection between the client and server.

The support provided by CADIMA mirrors the key steps of systematic reviews or systematic maps. CADIMA supports the following: 1) development of the review protocol; 2) management of search results (including the identification of duplicates); 3) management and conduct of the study selection process (including the performance of a consistency check); 4) management and conduct of on- and off-line data extraction; and, 5) management and conduct of the critical appraisal process. In addition, CADIMA ensures thorough documentation of the entire evidence synthesis process and allows for review results to be made publicly available: i.e. documents can be made

accessible to third parties if agreed by the review team. The permanent maintenance and further development of CADIMA is guaranteed by JKI and user support is provided to review teams via email. Furthermore, users can participate in online workshops or experiment using a test website before creating a full review.

In the following pages, we briefly describe CADIMA's main features, starting from the registration and customisation of a review and its team, to the conduct and documentation of the evidence synthesis process. In addition, we describe and summarise the different tasks within the review team and the information formats that are currently supported during the evidence synthesis process (see Table 3.2).

Table 3.2: Key features of CADIMA, different user roles and associated tasks and supported information formats used during the synthesis process.

Step	Key features of CADIMA	Roles and tasks	Information format
Set up the review	• Predefined input structure	***RC:*** • Invite registered use to become part of the review team • Define the title of the review • Define the question type (PICO, PIT, PO) • Define if a systematic review or a systematic map will be performed	• Manual entry
Protocol	• Predefined input structure referring to the key chapters of a protocol • Compile a drafted protocol document with potential annexes	***RC:*** • Mark those document blocks that should be compiled by CADIMA • Make final protocol publicly available ***All:*** • Enter/upload the requested information	• Manual entry • Upload/download formats: - Docx - Excel - Pdf
Literature search	• Documentation of the literature search • Indication of reports with missing abstract • Identification of duplicates	***All:*** • Allocate a search string to a search engine or a further information source it was applied • Uploaded search results	• Manual entry • Upload/download formats: - RIS files
Study selection	Support for the • Definition of selection criteria • Performance of a kappa-test - Takes a random sample of the identified reports to be rated by RC and/or RM - Kappa value will be provided • Online application of selection criteria - Title/abstract/full text will be co-displayed - Identification of discrepancies in the rating by RC and/or RM • Selection of studies that should be included in the review	***RC:*** • Set the criteria list as "final" • *Define those team members that should be involved in the kappa test* • *Decide about the suitability of the criteria based on the provided kappa value* • *Nominate team members to be involved during study selection* - *Decide about the application mode* - *Allocate identified reports* ***All:*** • Enter selection criteria • If nominated, apply criteria • Extract relevant studies	• Manual entry

Data extraction	• On- and offline data extraction	***All:*** • Define critical appraisal criteria • Define data extraction columns • Mark those columns relevant for the critical appraisal • Perform data extraction	• Manual entry • Online data extraction - manual entry • Offline data extraction - Download/upload of the data extraction sheet as excel file
Critical appraisal	• Co-display of extracted (meta-) data during the rating process • Online application of appraisal criteria • Identification of inconsistencies in reviewer judgments	***RC:*** • *Nominate team members to be involved during critical appraisal* - *Allocate relevant studies* ***All:*** • If nominated, critically appraise included studies	• Manual entry
Data synthesis	• Compilation of the data extraction sheet and the results from the critical appraisal	***All:*** • Perform the statistical analysis by using the software package of their choice • Upload of synthesis results	• Download format - Excel • Upload formats: - Excel - Docx - Pdf
Presenting data and results	• Thorough documentation (including any decision made during) of - Literature search - Study selection - Critical appraisal • Compilation of data extraction sheet • Opt for publication on the web site	***All:*** • Write up the review • Decide about and upload information to be made publicly available	• Download formats: - Excel - Docx • Upload formats: - Excel - Docx - Pdf

This table illustrates the key features of CADIMA for each step within the evidence synthesis process, describes the different user roles and associated tasks (RC= Review Coordinator, All= the entire Review Team), and specifies the information formats supported for each step. For more detail see text.

Registering with CADIMA and user roles

Users must register with the program in order to access the full functionality of CADIMA, which is free of charge (accessible via https://www.cadima.info/index.php/area/evidenceSynthesisDatabase). By accepting CADIMA's terms of service that regulate, besides others, the use of CADIMA and the handling of data (see Appendix 3.2), any registered user can initiate a new systematic review or map and can customise the review team. There are two different roles in a review team implemented in CADIMA. The 'review coordinator' manages the review and its team, and also performs more general tasks when compared to the one or more 'review team members' (see Table 3.2). Only the nominated members of the respective review team and the review coordinator can access the new evidence synthesis.

Structure of CADIMA

The menu structure of CADIMA mirrors the core steps and workflow of systematic reviews and systematic maps. This begins with the development of the review protocol (including the development of the review question), followed by the conduct of the literature search, study selection, data extraction, critical appraisal, data synthesis and the presentation of results. For each menu item, explanatory notes and submenus are provided. We now go on to explain the functionality of the different menu items in more detail.

Review protocol

At this stage, review authors are requested to detail information regarding the planned methods for the review, ensuring scientific rigour, transparency and repeatability. The input to CADIMA is provided by uploading remotely prepared blocks of text that correspond to key sections of a protocol. The overall format implemented in CADIMA resembles the draft of a protocol and has two major benefits: 1) it prevents important information from being unintentionally omitted; and

2) it facilitates peer-review of the protocol by ensuring that relevant information is included in the most appropriate section. Furthermore, CADIMA combines the respective text and generates one single document, which can then be formatted by the review team and submitted for peer-review.

Literature search

CADIMA is not a meta-search engine, such as PubMed or Scopus. Instead, CADIMA helps to structure and document the literature search by associating a search string with a search engine or further information source it was applied to, whilst the respective search results can be uploaded to CADIMA as RIS files. Following this, search results can be combined, duplicates removed, and records screened (see below). In addition, to facilitate the study selection process at title/abstract stage, CADIMA highlights those reports where an abstract is missing.

Study selection

The study selection step includes the following key aspects: 1) definition of selection criteria; 2) automated calculation of a kappa-statistic to test inter-reviewer agreement (http://handbook.cochrane.org/ (Part 2, chapter 7.2.6)) when applying the defined criteria; 3) screening of the records from the literature list according to the selection criteria at title, abstract and full text stage; and, 4) extraction of studies from eligible records (an important step that recognises the difference between a study [i.e. an independent unit of research] and an article [i.e. an independent unit of publication]). During the screening process, title, abstract and full text are displayed together with the selection criteria during each respective stage. Where records are independently assessed by more than one reviewer and inconsistencies between reviewers occur, they will be automatically identified by CADIMA and the respective reviewers asked to solve those conflicts.

Data extraction and critical appraisal

CADIMA is designed to encourage best practice in systematic reviewing, such as the requirement that reviewers specify their critical appraisal criteria prior to data extraction. Critical appraisal

criteria can refer to a specific bias under assessment (i.e. the internal validity of a study) and/or the generalisability of a study (i.e. its external validity). In addition, the critical appraisal judgement system (i.e. whether a distinction will be made between low, medium, high and unclear risk, or only between low, high and unclear risk etc.) and items for data extraction (i.e. which data should be extracted) must be defined. The data extraction sheet will automatically be generated by CADIMA and the reviewer can mark those data that are needed to inform critical appraisal.
CADIMA allows users to conduct either on- or off-line extraction of data and meta-data, by either directly entering information into CADIMA or by providing a download of the data extraction sheet as a spreadsheet file that can be uploaded once extraction is complete.
During critical appraisal, the appraisal criteria are used to assess the validity of included studies. CADIMA allows users to undertake critical appraisal online, while the extracted data relevant to the critical appraisal are shown together with the appraisal criteria. Where inconsistencies in coding decisions occur between two independent reviewers for one record, these will be automatically identified by CADIMA, and the respective reviewers are asked to resolve those conflicts.

Flexibility provided by CADIMA

CADIMA allows review steps to be modified and/or updated during the conduct of the review, with the exception of the selection criteria, since a change in the selection criteria would require the *de novo* performance of the consistency check and all previously extracted information would be lost. The core steps do not need to be undertaken in order: for example, search results can still be entered once the selection process has started, and the selection process does not need to be completed in order to start the data extraction or critical appraisal steps.
To support data synthesis activities, CADIMA provides the completed data extraction sheet and the results from the critical appraisal, as spreadsheets that facilitate data transfer and preparation for quantitative synthesis. These files can then be used by the review team to perform statistical analyses within the software package of their choice, such as R (https://cran.r-project.org/).

Presenting data and results

CADIMA facilitates thorough documentation of the review process, providing, besides others, the following information and data formats:

i. a flow diagram summarising the study selection process, satisfying PRISMA standards (http://www.prisma-statement.org/PRISMAStatement/FlowDiagram.aspx) (docx),
ii. reference lists for each database (xlsx) and the final reference list after duplicate removal (excel and RIS),
iii. the outcomes of the consistency check and study selection across the different stages (title, abstract and full text) including the reasons for exclusion (xlsx),
iv. the results of the critical appraisal (xlsx),
v. the filled data extraction sheet (xlsx).

Furthermore, CADIMA offers the possibility of uploading results generated by the review team, to make synthesis results available to third parties, i.e. displaying the documents on the web site and enable external users to download them. These features encourage a higher level of transparency than is common in published systematic reviews.

CADIMA and other types of evidence synthesis

CADIMA is also suitable for assisting in the process of conducting other forms of evidence synthesis, including systematic maps (Bragge et al. 2011; James et al. 2016) and rapid reviews (Collins et al. 2014) since not all steps of a systematic review have to be completed within the program. Consequently, the data extraction sheet can be designed to house meta-data only, and the critical appraisal step can be skipped completely if deemed necessary by the review authors.

Review of existing tools

Of the 22 software packages identified as being suitable to support the systematic review or systematic map process, nine were advertised as suitable for users from any field of research, nine were designed for the health care and medical science sectors, three were designed primarily for software engineering and one for experimental animal studies (Figure 3.1). The programs vary in terms of available support, and most offered graphical user interfaces (GUI), although four required prior knowledge of coding or software development to use. Web-based functions were available for 15 of the packages and seven involved downloadable applications. Most packages were designed for a team of reviewers, an important consideration given many guidelines require more than one reviewer to be involved with screening (e.g. CEE 2013). However, two packages did not provide this functionality. Of the primary stages of the systematic review process we identified, most software packages had the capacity to address article screening (most enabling title and/or title and abstract screening in addition to full text screening) (Table 3.3).

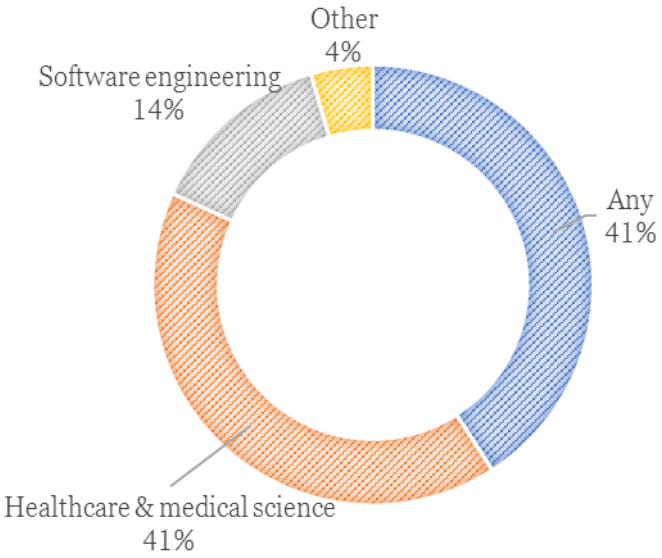

Figure 3.1: Breakdown of the intended fields of research each of the 22 software packages were primarily designed for.

Table 3.3: Breakdown of the 22 software packages designed to support evidence syntheses, with the functionality to support different stages of systematic reviews.

Software name	Setting up the review	Scoping/pilot study	Literature searching	Duplicate checking	Article screening	Data coding	Critical appraisal	Synthesis	Documentation
	Facilitation of question formulation and/or stakeholder engagement	Protocol development, PICO* elements specified	Software integrated with publication databases	Automated marking of duplicates	For study selection	Tagging and extraction to support meta-analyses	Risk of bias assessments	Facilitates quantitative/ qualitative syntheses of results	Output of text, figures or tables to assist with report writing
CADIMA	■	■		■	■	■	■		■
Colandr		■	■	■	■	■		■	■
Covidence				■	■	■	■		
DistillerSR			■	■	■	■		■	■
EROS					■	■	■		
EPPI-Reviewer 4			■	■	■	■	■	■	■
HAWC			■		■	■	■	■	■
METAGEAR package for R					■	■		■	
PARSIFAL		■	■	■	■	■			
Rayyan		■	■	■	■				
REviewER	■	■	■	■	■				
RevMan 5		■			■	■	■	■	■
RevMan Web	Data unavailable								
SESRA	■	■			■	■		■	■
SLR-Tool	■	■		■	■	■	■		■
SLuRp			■		■	■	■	■	■
SRDB.PRO			■	■	■	■	■	■	■
SRDR			■			■		■	
StArt		■		■	■	■	■	■	■
SUMARI			■		■	■	■	■	■
SWIFT-Review			■		■	■		■	■
SyRF	■	■	■		■	■	■	■	
TOTAL	5	10	13	11	20	19	12	15	13

*PICO: population (P), intervention (I), comparator (C) and outcome (O)

Machine learning and text mining features for use during screening, data extraction or synthesis stages are in their infancy, with only 10 software packages currently supporting or planning to support their use. To date these approaches have been incorporated into these tools in various ways, for example by assisting with article screening (e.g. Rayyan and EPPI-Reviewer), data extraction (e.g. METAGEAR package for R), and risk of bias assessments (e.g. SyRF). For further information about how text mining approaches have been effectively applied to systematic reviews, and more information about their potential future applications (see Thomas et al. 2011; O'Mara-Eves et al. 2015). Encouragingly, 16 software packages are freely available for non-commercial uses, and six are also open source. All of the software we assessed are available to use in English, although several lacked help documentation in English as they were designed primarily for use in another language (e.g. Molléri & Benitti 2013). Furthermore, some programs have advanced capabilities to manage articles in other languages and other character sets (e.g. DistillerSR).

During trialing of the software packages (summarised in Table 3.1), several general issues were noted. Most software packages lacked customisability; this was often to ensure compliance with specific existing guidelines or protocols within a particular discipline area (e.g. the Kitchenham guidelines for systematic reviews in software engineering (Kitchenham & Charters 2007)). This limits the degree to which many of the software packages can be used between disciplines. Most of the software packages differ in the types of input files they accept, and many only accept one type of input file (e.g. PubMed output files). The most common file type is RIS. This is problematic in interdisciplinary studies when importing studies from a wide range of sources and grey literature databases, many of which do not provide standardised export features (e.g. Google Scholar https://scholar.google.co.uk/, EU Joint Research Centre - Publications Repository http://publications.jrc.ec.europa.eu/repository, OECD iLibrary http://www.oecd-ilibrary.org/). To help address this, EPPI-Reviewer developers have

designed a RIS converter to convert other file formats such as CSV files to RIS format (http://eppi.ioe.ac.uk/cms/Default.aspx?tabid=2934).

Duplicate checking is an increasingly common feature (Table 3.3) that can provide valuable time savings, particularly if duplicate detection can be partially automated (e.g. EPPI-Reviewer). Automated import of abstracts and full-text PDFs is also an important time-saving feature in larger studies but is not yet widely available (and is difficult when many studies are not open access, as in the field of conservation biology).

Discussion and outlook

There is increasing demand for information management systems which assist with the centralisation and management of the systematic review process, to improve efficiency and to facilitate teams of reviewers to collaborate. We have identified 22 software packages which provide this functionality, designed for users from a wide range of disciplines. There is a large degree of overlap between many of these software packages, however most have been developed with particular disciplines in mind and lack the customisability suitable for access and use by reviewers across disciplines. As a general observation, many developers appear to have developed these tools without an awareness of the full range of similar tools available (a point also noted in a recent systematic review (O'Mara-Eves et al. 2015)).

EJM (who was not part of the development team) trialled CADIMA and found it intuitive to use and noted it performed smoothly even with large datasets. A major benefit of CADIMA is the fact it is suitable for teams (vital for reviewers following certain guidelines (e.g. CEE 2013)) and is free and well supported – an important consideration for students, small organisations and not-for-profits (even low monthly fees are barriers, as the typical review process can take over a year). CADIMA also offers greater security than traditional approaches to review management, such as Microsoft Excel, when it comes to sorting records and tracing included

articles between different stages of the screening and data extraction process. The ability to export files and work offline easily with CADIMA was considered a great asset, although the linear structure of the application has so far precluded adjustments to review team membership between screening stages. The developers have taken this into consideration for future developments of the programme. As CADIMA combines many different stages of the review process in a single piece of software, it also has the advantage of enhancing transparency and replicability.

CADIMA is designed to provide important information to users in the form of prompts, which make the difference between a rigorous systematic review and a standard literature review, considerably reducing the barrier to entry for first time reviewers. These include protocol development prompts which mirror Collaboration for Environmental Evidence guidelines, and stages such as consistency checking. The structure and layout of CADIMA encourages users to document their methodology and screening criteria clearly, and also provides a location for record and methods to be hosted online, so that subsequent revisions can be undertaken easily. Like CADIMA, the majority of software packages support teams of reviewers, require no prior coding knowledge and offer a range of help and support, facilitating rapid learning and working with a team of individuals with differing degrees of experience. A handful of tools are particularly designed to lead the user in a stepwise manner through the review process, including CADIMA with its inbuilt guidance and clear layout, and SESRA (Molléri & Benitti 2013), which mirrors the stages in the Kitchenham and Charters guidelines (Kitchenham & Charters 2007). Others, such as EPPI-Reviewer, do not follow this structured approach, and users design the stages according to their needs, meaning they must be familiar with both the software and systematic review methodology.

No single software package guides the reviewer through all stages of a systematic review or map project (from question formation to the exporting of project documentation), meaning stages such as literature searches or analysis and writing up of results are often expected to be

managed separately. This is also true for CADIMA, which provides support for the majority of the stages we assessed (Table 3.3), excluding built-in searching and quantitative synthesis. Just over half of the software packages are integrated with one or more publication databases to allow for built-in searching, however this inevitably limited them to certain databases and their associated disciplines, such as PubMed (medical and healthcare evidence, https://www.ncbi.nlm.nih.gov/pubmed/) in the case of DistillerSR, SRDB.PRO, SWIFT-Review and SyRF.

The principal advantage of using software to assist in managing the review process is to increase efficiency of time-consuming tasks, to allow for efforts to be concentrated on the most important tasks – namely synthesis and analysis. CADIMA facilitates the importing and exporting of the results of searching and synthesis to allow literature searches and statistical analysis to be conducted flexibly, using alternative software, and focuses on simplifying the tracking of large numbers of review articles throughout the process.

Future developments of CADIMA

Based on the results of the conducted review and received user feedback, the following issues will be considered during the next round of development for CADIMA:

- To facilitate the exchange between CADIMA and different reference sources, additional input formats will be catered for, rather than RIS files only;
- Duplicates are detectable within CADIMA but cannot be automatically removed in the current version. This can be quite time consuming in cases where many duplicates are identified. In such cases, review teams can automatically delete duplicates, for example by using EndNote and import the cleared list to CADIMA. In the future, an automated removal process will be implemented to CADIMA;

- In order to speed up the study selection process at title/abstract stage, text mining approaches will be tested and potentially implemented in the event a demonstrably robust method is developed (currently the software RapidMiner https://rapidminer.com/) is used to trial the use of text mining during the selection process);
- To increase the time savings offered by CADIMA, an automated upload of PDFs at full-text screening stage is planned;
- Currently, the same reviewers have to participate during the study selection process at title, abstract and full text stage. In the future, the possibility will be provided that different reviewers can be involved during the respective stages; and
- Due to the limitations associated with the conduct of a full systematic review, further evidence synthesis approaches, such as rapid reviews, are evolving in order to save resources and to provide a timely answer to a posed question (Collins et al. 2014; Roll et al. 2018). This is especially important in the political context where time is a major consideration. A future goal for CADIMA is to allow people to customise their review, depending on the purpose of the synthesis and available resources.

CADIMA will continue to be developed to join several other software packages which make use of machine learning approaches to increase efficiency at the article screening stages of the systematic review process. This is an area that we believe will be of increasing interest to users, particularly for updating existing reviews (algorithms can be trained to identify relevant studies based on similarity to previously included studies (Khangura et al. 2012)) and dealing with very large bodies of literature.

The use of new technology to assist the systematic review process is a rapidly developing area, demonstrated by the inclusion of three new or upgraded software packages expected to become live in 2017 in our review (plus another we were unable to find further information on; DRAGON ONLINE). Several other packages which came up in our search have been

discontinued, suggesting security of funding, ongoing maintenance and continual improvement are essential considerations for the developers of these types of software packages to prevent them quickly becoming obsolete.

Conclusions

From a user perspective, we believe that CADIMA stands out in terms of ease of use, support for multiple users, support for on- or off-line data extraction, commitment to ongoing maintenance and financing, therefore meeting the criteria rated as most important by users of systematic review software in a recent study (Marshall et al. 2015). Many other free software packages require prior experience of software development and computer coding or have limited capacity for ongoing maintenance. Aside from CADIMA, those that are continually updated and provide user-friendly graphical user interfaces, tend to be expensive for team reviews, making them less feasible options for small research teams or non-profit organisations.

Acknowledgements

The authors wish to thank Simone Frenzel for her help during the development of CADIMA, GRACE team members for their input and Andrew Pullin for his support when establishing the collaboration between JKI and CEE.

Correction

A correction to this article has been published in Environmental Evidence 2018 7:12

The authors wish to update information about the software DistillerSR in Tables 3.1 and 3.3 which we were alerted to following the publication of original article. In addition to the analysis provided, DistillerSR does support protocol development (Pi) e.g. assistance to determine appropriate PICO elements, and critical appraisal (Cr) as 'stages of the SR process supported'. This information was not originally included in the assessment due to a lack of clarity on the

service providers' website. No further updates to this manuscript will be possible for this or other software, in line with the general disclaimer below.

General disclaimer:

The review of systematic review support software represents an independent assessment by EJ McIntosh based on publicly available information on each software package. This assessment represents an attempt to best capture information located via service providers' websites, in academic publications, user manuals and via free trials or software demonstrations. Occasionally, relevant information was not publicly available or may have been difficult to access or interpret. This assessment does not represent the views or opinions of any of the software developers or service providers. The review of software was completed in mid-2017, readers should visit the software providers' websites (linked in Table 3.1) to check for updates, for further information and to seek clarification where necessary.

4

Paper 4: Absence of evidence for the conservation outcomes of systematic conservation planning around the globe: A systematic map

The published article is available online:

McIntosh EJ, Chapman S, Kearney SG, Williams B, Althor G, Thorn JPR, Pressey RL, McKinnon MC, Grenyer R. 2018. Absence of evidence for the conservation outcomes of systematic conservation planning around the globe: A systematic map. Environmental Evidence 7:e1-23. Doi: 10.1186/s13750-018-0134-2

This text reflects the accepted manuscript but may not include minor editorial changes made prior to publication.

Abstract

Background: Systematic conservation planning is a discipline concerned with the prioritisation of resources for biodiversity conservation and is often used in the design or assessment of terrestrial and marine protected area networks. Despite being an evidence-based discipline, to date there has been no comprehensive review of the outcomes of systematic conservation plans and assessments of the relative effectiveness of applications in different contexts. To address this fundamental gap in knowledge, our primary research question was: What is the extent, distribution and robustness of evidence on conservation outcomes of systematic conservation planning around the globe?

Methods: A systematic mapping exercise was undertaken using standardised search terms across 29 sources, including publication databases, online repositories and a wide range of grey literature sources. The review team screened articles recursively, first by title only, then abstract and finally by full-text, using inclusion criteria related to systematic conservation plans conducted at sub-global scales and reported on since 1983. We sought studies that reported outcomes relating to natural, human, social, financial or institutional outcomes and which employed robust evaluation study designs. The following information was extracted from included studies: bibliographic details, background information including location of study and broad objectives of the plan, study design, reported outcomes and context.

Results: Of the approximately 10,000 unique articles returned through our searches, 1,209 were included for full-text screening and 43 studies reported outcomes of conservation planning interventions. However, only three studies involved the use of evaluation study designs which are suitably rigorous for inclusion, according to best-practice guidelines. The three included studies were undertaken in the Gulf of California (Mexico), Réunion Island, and The Nature Conservancy's landholdings across the USA. The studies varied widely in context,

purpose and outcomes. Study designs were non-experimental or qualitative, and involved use of spatial landholdings over time, stakeholder surveys and modelling of alternative planning scenarios.

Conclusion: Rigorous evaluations of systematic conservation plans are currently not published in academic journals or made publicly available elsewhere. Despite frequent claims relating to positive implications and outcomes of these planning activities, we show that evaluations are probably rarely conducted. This finding does not imply systematic conservation planning is not effective but highlights a significant gap in our understanding of how, when and why it may or may not be effective. Our results also corroborate claims that the literature on systematic conservation planning is dominated by methodological studies, rather than those that focus on implementation and outcomes, and support the case that this is a problematic imbalance in the literature. We emphasise the need for academics and practitioners to publish the outcomes of systematic conservation planning exercises and to consider employing robust evaluation methodologies when reporting project outcomes. Adequate reporting of outcomes will in turn enable transparency and accountability between institutions and funding bodies as well as improving the science and practice of conservation planning.

Keywords

Conservation assessment; prioritisation; resource allocation; evidence synthesis; protected areas; implementation

Background

Conservation planning is "the process of making informed conservation decisions" (Groves & Game 2016a). It is particularly important given the scale and complexity of policy and institutional agendas when it comes to spatially allocating resources. An approach to conservation planning that has received widespread interest for its evidence-based approach amongst academics (Sarkar et al. 2006; Kukkala & Moilanen 2013), conservation organisations (Groves et al. 2002; Morrison et al. 2009) and government departments (Cowling & Pressey 2003; Brownlie et al. 2005; Fernandes et al. 2005) alike, is the discipline of systematic conservation planning (Margules & Pressey 2000).

Systematic conservation planning emerged in the 1980s and 1990s as a response to the tendency of conservation decisions to be made in an *ad hoc* manner. The majority of terrestrial protected areas were designated in places that were steeply sloped or otherwise unsuitable for agriculture, rather than where biodiversity was highest and most in need of protection (Pressey 1994; Venter et al. 2017). Systematic conservation planning built on ranking approaches, popular before the early 1980s, by incorporating quantifiable objectives and enabling assessments of trade-offs between competing conservation and cost-effectiveness considerations (Pressey & Nicholls 1989).

Ecological principles such as representation and persistence are central to systematic conservation planning (Kukkala & Moilanen 2013). Terminology has changed over time (for political expediency; Pressey, in prep) since the CAR (comprehensiveness, adequacy, representativeness) principles that first drove the discipline. Here, representation refers to the extent to which a set of reserves samples the full biodiversity of a region (combining both the original uses of comprehensiveness and representativeness). Persistence (originally framed in terms of adequacy) means the long-term survival of species or other elements of biodiversity,

including diverse natural processes at a variety of scales (Watson et al. 2011), often approached through connectivity of multiple species and habitats across landscapes and seascapes.

Systematic conservation planning proposes a structured, consultative process for choosing between, locating, configuring, and implementing conservation actions, often involving input from policy makers, land managers and resource users. Conservation objectives are specified quantitatively, in one of two ways (Carwardine et al. 2009). First, and most commonly, objectives are expressed as threshold amounts of natural features relative to a baseline. An example is to cover at least 20% of each vegetation type, with no explicit added benefit for amounts over 20%. Second, objectives can be defined as continuous functions that accrue benefit up to 100% coverage of features. The outputs are optimal or near-optimal sets of spatially-bounded conservation actions (McIntosh et al. 2016, 2017) (Figure 4.1).

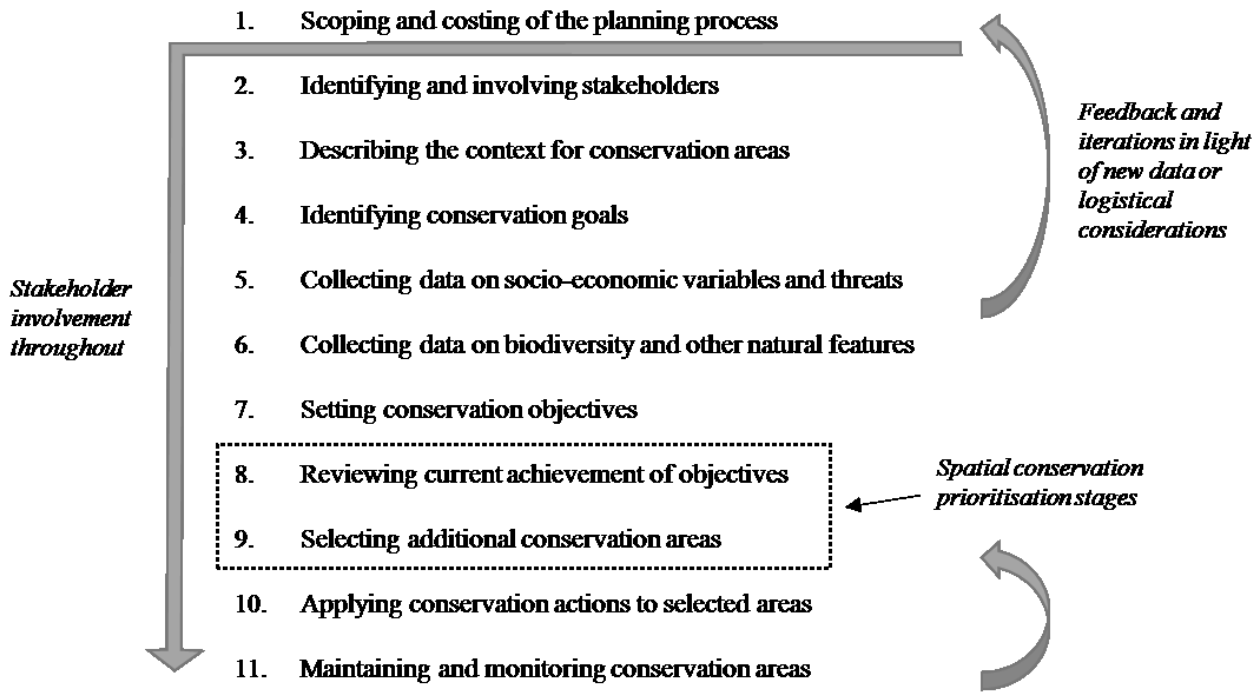

Figure 4.1: The stages of systematic conservation planning, reproduced from (McIntosh et al. 2016) and originally modified from (Pressey & Bottrill 2009). Conservation planning approaches that are more systematic tend to follow these general steps. We define systematic conservation planning initiatives as those that also make use of spatial prioritisations and associated computational decision-support tools during stages 8 and 9 (boxed).

During the planning process, spatial conservation prioritisations (also called conservation assessments) are conducted, often using decision support software such as Marxan (Ball & Possingham 2000), Marxan-with-Zones (Watts et al. 2009), Zonation (Lehtomäki & Moilanen 2013), and C-Plan (Pressey et al. 2009) (Figure 4.1) to sort through the vast number of potential spatial configurations. While often equated with systematic conservation planning, prioritisations are analytical exercises making up only a subset of the overall process (McIntosh et al. 2017).

Rigorous evidence is central to systematic conservation planning. This generally includes spatial data for biodiversity or environmental surrogates (Watson et al. 2011) and socio-economic cost predictors such as land acquisition costs or willingness of landowners to support proposed conservation activities (Knight et al. 2011b). Plans often also include assessments of vulnerability to future climatic regimes (Jones et al. 2016) and analyses of scheduling conservation actions over time (Visconti & Joppa 2014).

The discipline of systematic conservation planning has had a major influence on conservation planning practices globally. It is used extensively by environmental organisations and government agencies alike (Groves & Game 2016a). Thousands of academic publications focus on the discipline, a trend that appears to be increasing (Kukkala & Moilanen 2013; Kullberg & Moilanen 2014). Marxan alone had over 6,700 users from 184 countries between 2011 and 2016 (Watts 2018). Efforts are currently underway to centralise records about where systematic conservation plans have been developed (Álvarez-Romero et al. 2018), as the number of total plans is currently unknown.

This type of planning is resource intensive and can cost millions of dollars over several years (Pressey & Bottrill 2009). Despite the influence of the discipline and the importance of evidence when developing plans, there is very little rigorous evidence about whether systematic

conservation planning is effective at improving biodiversity conservation outcomes (Bottrill & Pressey 2012). A compilation of such studies is therefore much needed.

This study outlines the results of a systematic mapping exercise to comprehensively assess the published literature on the effectiveness of systematic conservation planning (McIntosh et al. 2016). Systematic maps are typically precursors to systematic reviews, and involve collating, describing and assessing the quality of studies assessing a particular intervention (James et al. 2016). To our knowledge, this is the first systematic map of a planning intervention in the environmental sciences, and it introduces a new set of challenges in evidence availability and interpretation. Interest in this topic is not new and this study follows a preliminary protocol for a systematic review lodged with the Collaboration for Environmental Evidence in 2008 (Bottrill & Pressey 2009).

Our conceptual understanding of how systematic conservation planning interventions can lead to outcomes in terms of natural, human, social, financial and institutional capital is illustrated in Figure 4.2 and expanded in Table 4.1. This theory of change is deliberately simple, to illustrate the potentially broad range of outcomes currently assumed to result from systematic conservation planning exercises (Bottrill & Pressey 2012). Multiple pathways and mechanisms are likely to link systematic conservation planning to these outcomes, but these are not yet consistently defined. Our decision to report outcomes by five types of capital follows an earlier application of this framework to conservation planning (Bottrill et al. 2012) and related disciplines e.g. (Garnett et al. 2007). For further details, see our published protocol (McIntosh et al. 2016).

Table 4.1: Potential outcomes of systematic conservation planning arranged according to capitals. Categories adapted from the typology developed by Bottrill and Pressey (2012) *(representativeness was removed as an example of a natural capital outcome (Pressey et al. 2017)).*

Capital	Definition	Outcome sub-category
Natural	The stock and flow of goods and services provided by ecosystems, including the diversity of species, regulating processes, and supporting services (Costanza et al. 1997).	Reduction in loss or degradation of natural values Persistence of biodiversity Maintenance of ecosystem services
Financial	The gain or loss of cash, property or assets that represent the economic value of an individual or organisation.	Transparency in conservation investments Efficiency of operations Maximised benefit given limited budget Leverage of additional funds or in-kind support
Social	Represents the relationships and interactions between individuals and groups (Pretty & Ward 2001).	Collaboration among agencies Coordination between different actors Trust in planning process Sharing datasets between agencies Shared vision Attitudes of stakeholders Power dynamics between stakeholders
Human	Knowledge or skills that enable people to develop strategies to achieve their objectives (DfID 1999).	Raised awareness of biodiversity or conservation New knowledge of ecological or social values Learning applied in future plans
Institutional	Capacity, structure, or functioning of institutions through formal (e.g. laws) or informal means (e.g. local governance practices) (Platje 2008).	Influence on future decision making by organisation or partners Self-sustaining strategies Role of implementing agency Consideration of conservation issues in decision making by other sectors Integration of priorities into policies, conventions or legislation Influence on resource-use planning Protected areas expanded

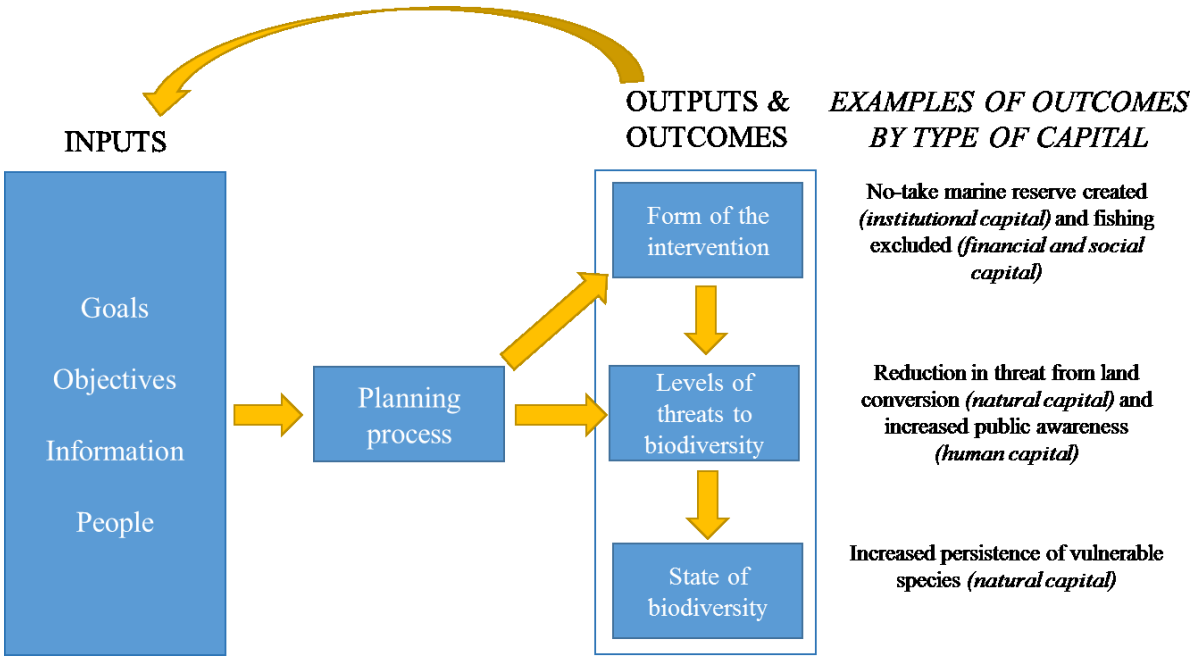

Figure 4.2: A conceptual model for systematic conservation planning (reproduced from the protocol (McIntosh et al. 2016)). A range of inputs influence the planning process. Outputs and outcomes can arise throughout the planning process but, for simplicity, we have lumped the main stages during the planning process. Different types of outputs from the planning process will lead to different types of outcomes. However, given the causal chains are not yet well understood, single arrows have been used to indicate the influence of the planning process on the types of potential outputs and outcomes. Outputs are the material or legal products of inputs, such as numbers or total km² of protected areas or numbers of boats available to patrol for illegal fishing. Outcomes are the observed or assumed effects of outputs, including reduced threat levels and improved state of biodiversity (Pressey et al. 2017). The feedback arrow from outcomes to inputs indicates the adaptive approach used to modify plans subject to observed outcomes.

Stakeholder engagement

Subject experts (ranging from academic researchers to staff in environmental NGOs responsible for conducting systematic conservation plans) were consulted throughout the protocol development, searching and analysis stages. This occurred in several ways. Calls were put out for comment at relevant conferences and workshops, alongside presentations and posters about the project. Subject experts were also invited to share potentially relevant studies (see Methods) and this usually led to email or phone discussions about the research and findings, as well as recommendations for additional contacts.

Objective of the systematic map

We sought to identify retrospective studies that measured the effects of systematic conservation planning exercises on biodiversity conservation at various scales. Our primary research question was: What is the extent and distribution of evidence on conservation outcomes of systematic conservation planning around the globe? The definitions used to focus our search are provided in Table 4.2.

Table 4.2: Subject, intervention, outcome and comparator search elements.

Search element	Definition
Subject (Population)	All countries and marine, freshwater and terrestrial realms. Studies published between 1983 and 2017.
Intervention	Systematic conservation planning: a process for locating and implementing conservation actions where: a) the benefits of conservation actions are specified either as threshold amounts of natural features to be represented or as continuous functions with increasing amounts of features; and b) the outputs are one or more optimal or near optimal sets of spatially-bounded conservation actions.
Comparator	Comparisons over time, and/or between control and intervention groups and/or sites.
Outcome	Studies measuring changes in the condition of one or more of the following forms of capitals: natural, financial, social, human and institutional (either quantitatively or qualitatively).

Our intent was to categorise included studies using a data extraction framework. The framework was designed to explore the following secondary questions:

- What are the characteristics of the current evidence base, including study location, scale and study design, intervention and outcome type?
- What types of outcomes of systematic conservation planning exercises are measured, either by the original planning organisation(s) or others?

- What types of study designs are used in evaluations of systematic conservation planning?
- How robust is existing evidence? How many impact evaluations have been conducted, where and by whom?

Methods

Our systematic map protocol has been published in *Environmental Evidence* (McIntosh et al. 2016; Paper 2) and this section includes updates since that publication. Updates include the use of the software CADIMA, consistency checks prior to every screening stage and abandonment of an attempt to undertake the bulk of screening by one reviewer (up to six were involved in the most time-consuming stages). Also, no evidence matrix (a visual depiction of the volume and quality of evidence, with interventions types on one axis and outcomes on another) was produced due to the small sample size. Further details have been provided in related sections of the methods.

Search strategy

A search string, consisting of subject- intervention- and outcome-related keywords combined using Boolean logic and wildcards, was used to query publication databases, search engines and online repositories (Table 4.3). Searches were conducted in February and March 2017. Unless otherwise indicated, searches were conducted for studies produced between 1983 and 2017 inclusive, in English only given resource constraints. Publications with full-texts not in English were listed and recorded separately for future iterations of the map or for other interested parties to pursue (see Results).

Table 4.3: Search terms and strings used for searching online databases and websites.

Publication database search terms (formatted for Web of Science) [a]

Subject terms AND Intervention terms AND Outcome terms AND Qualifier terms	TS=(aquatic OR "river basin" OR ecoregion* OR bioregion* OR terrestrial OR marine OR freshwater OR coastal OR landscape OR seascape OR catchment OR "coastal zone" OR "ecological network" OR corridor OR "conservation area" OR "reserve network" OR "protected area" OR "national park" OR "planning unit") AND TS=("conservation plan*" OR "spatial plan*" OR "conservation assessment" OR "reserve selection" OR "area selection" OR "reserve design*" OR "conservation zoning" OR "key biodiversity area" OR "important bird area" OR "spatial priorit*"OR "conservation priorit*" OR "conservation area priorit*" OR "spatial optimi*" OR "protected area network design" OR "resource allocation" OR "conservation decision making" OR marxan OR zonation OR "C-Plan" OR RobOff OR BioRap OR CLUZ OR ConsNet OR CPLEX OR CREDOS OR "Ecoseed Marzone" OR MinPatch OR MultCSync OR NatureServeVista OR ResNet OR SPEXAN OR "conservation evaluation" OR "area identification" OR "decision-support tool" OR "conservation action") AND TS=(outcome* OR evaluat* OR output* OR impact* OR effect* OR ineffective OR success* OR fail* OR benefit* OR implement*) AND TS=(biodivers* OR wildlife OR species OR habitat)

Google Scholar search terms

	"conservation plan" "conservation planning" "spatial plan" "conservation assessment" "reserve design" "conservation zoning"

[a] Following sensitivity testing during initial pilots of the searches (in November 2016), the search terms were revised from the original protocol (McIntosh et al. 2016). Terms were removed if they either inflated the number of search terms returned in an unspecified way (i.e. adding a large number of irrelevant search results), or if they did not add value to searches based on similarity to existing terms.

To ensure wide coverage of potential peer-reviewed academic publications and grey-literature publications (Haddaway & Bayliss 2015), we searched three publication databases, one search engine, three online repositories, and 21 organisational websites (Table 4.4). Studies were also identified opportunistically, via calls for papers at major international conferences, backwards and forwards citation searches of included studies (in March 2018) and use of review papers to identify related primary studies. Subject experts were contacted to confirm no key references were missed. These individuals were identified primarily by their roles as conservation

planning experts within global conservation NGOs, such as Conservation International, and prominent national organisations, such as the South African National Biodiversity Institute, and through snowball sampling (many recommended additional subject experts). Experts also included academics whom the authors knew had an interest in this topic. The detailed protocols employed to search each source, including tailored approaches to individual databases and suggestions from subject experts, are outlined in Additional File 4.1.

Table 4.4: Sources searched and search methods according to source type.

Source type	Source	Weblink	Search method*
Publication database	Web of Science ™ Core Collection	www.webofknowledge.com	Searched on title, abstract and keywords using the publication database search string adapted for each database.
	SCOPUS	www.scopus.com	
	CAB Abstracts	https://www.cabi.org/publishing-products/online-information-resources/cab-abstracts/	All results extracted.
Search engine	Google Scholar	www.scholar.google.co.uk	Searched on title only using the Google Scholar search string. A second search required 'evaluation' to also appear in the title. For both searches, the first 1,000 results were retrieved using the software Harzing's Publish or Perish (Harzing 2007).
Online repositories	Open Grey	http://www.opengrey.eu/	Searched on title only, using the Google Scholar search string
	PAIS International (ProQuest)	http://www.proquest.com/products-services/pais-set-c.html	
	Proceedings First (OCLC Online Computer Library Center, Inc.)	http://www.oclc.org	
	Papers First (OCLC Online Computer Library Center, Inc.)	http://www.oclc.org	
Websites of specialist organisations and online databases	Campbell Collaboration	www.campbellcollaboration.org/lib/	Where possible, organisational databases and websites were searched on all text using the

Source type	Source	Weblink	Search method*
			Google Scholar search string with Boolean operators.
	Center for International Forestry Research (CIFOR) - Library	www.cifor.org/library/	Where within-website searches could not be conducted on the whole Google Scholar search string using Boolean operators, individual terms were searched, and the resultant search lists combined, and duplicates removed.
	Environmental Evidence	www.environmentalevidence.org	
	Conservation Evidence	www.conservationevidence.com	
	Coral Triangle Initiative	http://www.coraltriangleinitiative.org	
	Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia	https://publications.csiro.au/	
	Evidence on Demand	http://www.evidenceondemand.info/library.aspx	
	IUCN Evaluations database	https://www.iucn.org/monitoring-and-evaluation/monitoring-our-work/evaluations-database	
	IUCN Library System	https://portals.iucn.org/library/dir/publications-list	
	Natureserve	http://www.natureserve.org/biodiversity-science/publications	
	Poverty and Conservation Learning Group - Bibliographic database	https://www.povertyandconservation.info/en/bibliographies	
	Poverty and Conservation Learning Group - Biodiversity-poverty evidence database	https://www.povertyandconservation.info/biodiversity-poverty-evidence	
	Poverty and Conservation Learning Group - PCLG publications	https://www.povertyandconservation.info/en/pclg-publications	
	Protected Planet	www.protectedplanet.net	
	SANBI Planning database, South Africa	http://www.sanbi.org/information/documents	
	The Digital Observatory for Protected Areas (Europe)	http://dopa.jrc.ec.europa.eu/en/documentation	

Source type	Source	Weblink	Search method*
	United Nations Environment Programme – World Conservation Monitoring Centre	https://www.unep-wcmc.org/resources-and-data	
	Biodiversity Heritage Library	http://www.biodiversitylibrary.org/	
	USAID Development Experience Clearinghouse (Evaluations)	https://dec.usaid.gov/dec/content/evaluations.aspx	
	USAID Biodiversity Conservation Gateway	https://rmportal.net/biodiversityconservation-gateway	
	World Wildlife Fund for Nature International	wwf.panda.org	
Opportunistic	Four academic conferences		General calls were made during presentations and on Twitter
	Subject experts		Requests were made via email

*Detailed records of the dates and criteria used for each search are included in Appendix 4.1

Data management

Following the searches, article citation details and abstracts were extracted in .ris form (or converted to .ris form using a freely accessible conversion template developed for our purposes by the EPPI-Centre (EPPI-Centre n.d.)). When searching websites, the web scraping software Parsehub (https://www.parsehub.com) was used to extract records (Stansfield et al. 2016; Haddaway et al. 2017). Settings were tailored to each website and details are provided in Additional File 4.1.

Results were initially imported into the software EPPI-Reviewer (V.4.5.1.0 (Thomas et al. 2010)), which was used to detect and remove duplicate articles. Prior to title screening, duplicate checked results were imported into the systematic review management software CADIMA (Kohl et al. 2018).

Article screening and inclusion criteria

Articles were screened in three stages: title only, abstract, then full-text. When screening articles for relevance, a series of inclusion and exclusion decisions were consistently applied (Table 4.5). Regular reviewer team meetings were held throughout all screening stages to ensure criteria were being applied uniformly, and detailed decision rules were tailored for each screening stage in these meetings. During our discussions about definitions of systematic conservation planning and tightening the inclusion criteria, we revised our original positions and excluded several studies we had expected to include at the protocol development stage (from the test library, including Fernandes et al. 2005; Osmond et al. 2010; Weeks et al. 2014). If there was any doubt about the relevance of an article, it was included for evaluation in the subsequent screening round to avoid removing potentially relevant studies. Two of the authors (MCM and RLP) have published extensively in this field so were not involved in article screening to reduce the likelihood of authors reviewing their own work.

Table 4.5: Article inclusion and exclusion criteria, summarised from the protocol (McIntosh et al. 2016) with practical considerations adopted during screening to increase clarity and consistency in the application of the criteria.

Screening criteria	Relevant	Irrelevant	Practical clarifications
Subject	Inclusive of all countries and marine, freshwater and terrestrial realms. Studies published between 1983 and 2017.	Global-scale plans. Studies published prior to 1983.	Studies conducted at continental or smaller scales were included.
Intervention	Systematic conservation planning: a process for locating and implementing conservation actions where: a) the benefits of conservation actions are specified either as threshold amounts of natural features to be represented or as continuous functions with increasing amounts of features; and b) the outputs are one or more optimal or near optimal sets of spatially-bounded conservation actions. This means that plans will necessarily use existing (e.g. Marxan (Ball & Possingham 2000), C-Plan (Pressey et al. 2009) and Zonation (Lehtomäki & Moilanen 2013)) or custom-made (e.g. linear/non-linear programming, genetic algorithms) decision-support tools in the 'spatial prioritisation' stages.	Studies relating to plans that have no explicitly stated (or quantifiable) biological conservation objectives. Studies relating to plans that were solely expert-based approaches. Studies that do not involve the use of computerised decision-support tools.	Studies were included if they approximated the stages of systematic conservation planning in Figure 4.1 (e.g. plans did not have to have been implemented), and involved stakeholder engagement, quantifiable conservation objectives, and a spatial prioritisation exercise.
Outcome	Studies measuring changes in the condition of one or more of the following forms of capitals: natural, financial, social, human and institutional (either quantitatively or qualitatively). Broad interpretation of outcomes to capture the breadth of intended and unintended outcomes and potential flow-on consequences for biodiversity conservation. *	Outcomes that are not attributed to a systematic conservation planning process.	Studies were included if they reported on changes in the condition of one or more types of capital, *as a result of* a systematic conservation planning.
Comparator	Comparisons over time (continuous or interrupted time series**), and/or between control and intervention groups and/or sites.	Studies that measure at a single point in time, with no comparison to another site.	Opinion-based assessments were excluded.
Study design	Retrospective quantitative and qualitative experimental, quasi-experimental and non-experimental designs according to Margoluis et al. (Margoluis et al. 2009).	Theoretical studies, prospective models, or studies using only ex-post modelling to estimate business as usual versus future planning scenarios were excluded, as were	Relevant study designs had to relate to the impact of a conservation action (e.g. baseline monitoring was not necessarily suitable). To distinguish gap analyses from impact

	studies based on researcher inference.	evaluations, studies using measures of representativeness in a gap analysis scenario were excluded. Opinions of the authors or unsubstantiated statements were treated as 'researcher inference' and excluded on study design.

*A detailed discussion of what constitutes an outcome versus an impact is provided in (McIntosh et al. 2017).

**In an interrupted time series, data are collected at several time points before and after an intervention (Ramsay et al. 2003).

Prior to commencing each screening stage, inter-reviewer consistency checks were conducted with the reviewers involved at that stage. A subset of the same titles/abstracts/or full-texts were screened by all and results were compared using Cohen's Kappa (*k*) (Carletta 1996) (more details below). This exercise was repeated, and inclusion rules clarified, until the desired level of consistency was met (threshold *k* value of 0.5 at title screening and 0.7 for abstract and full-text screening). These *k* values exceed recommended guidelines (CEE 2013). After this, screening formally started (the articles used in consistency checks were included again in the overall screening). Articles were randomly divided between the reviewers and were not duplicate screened (except those marked as unsure, and at full-text extraction stage). Articles provided by subject experts were automatically included for screening at full-text.

Title screening

For title screening, four rounds of consistency checks were required, involving 200 randomly selected articles each time (800 titles total). Rounds were iteratively undertaken using CADIMA until screening decisions were above the $k = 0.5$ threshold. Publication titles were reviewed in CADIMA by two reviewers in accordance with the inclusion and exclusion criteria.

Abstract screening

Due to limitations of CADIMA (not allowing changes to the size of a reviewer team at different stages (Kohl et al. 2018)), EPPI-Reviewer was used for abstract and full-text screening. Missing abstracts were entered for included articles. Six reviewers participated in abstract screening and five rounds of consistency checks were conducted, each involving 25 randomly selected articles, until results exceeded the $k = 0.7$ threshold (125 abstracts total).

Full-text screening

Full-text files were downloaded or accessed in hard copy through the Bodleian Libraries at the University of Oxford. Full-text articles were divided between and screened by three reviewers following six rounds of consistency checks (where 20 articles were screened by all three reviewers each round), until results exceeded the $k = 0.7$ threshold (120 full-texts). Reviewers included articles focusing on those with relevant subject, intervention, outcomes, comparator and study designs (Table 4.5). Articles were included only when all five criteria were relevant. Where insufficient information was provided to determine if the intervention met our definition of systematic conservation planning, further information was sought before reaching a decision, such as by following up cited references about the original plan. Any articles the reviewer was unsure about were flagged as 'unsure' and were discussed with the other reviewers prior to reaching a decision. Given inconsistencies in the use of the term "systematic conservation planning" (McIntosh et al. 2017), those studies for which the "intervention was similar to, but not systematic conservation planning" (according to our definition, Table 4.5) were marked as such. This provided estimates of the number of spatial conservation prioritisations and other related exercises detected. Review papers were also set aside, and the studies therein were assessed for relevance.

Data coding and mapping

Relevant studies were extracted from the included articles (where multiple studies were included in a single article). For example, a single paper often reported on multiple planning instances. The included studies were categorised by two reviewers according to a data coding template (Additional File 4.2) and any differences in coding were discussed and a third reviewer involved if necessary (undertaking kappa analysis was unnecessary at this stage due to the small sample size). Coding involved outlining bibliographic details, background information including location of study and broad objectives of the plan, study design, reported outcomes and context (McIntosh et al. 2016). Information about the study design of relevant articles was recorded to determine study robustness (e.g. experimental, non-experimental), in place of critical appraisal of included studies (which is beyond the scope of a systematic map). Where possible, the categories of the data coding template were updated to match those underlying a new database of marine spatial prioritisations (Álvarez-Romero et al. 2018) to make the two databases cross-compatible. Where necessary, we contacted authors of included studies for additional information (via email or phone).

Our finding of fewer than expected evaluations in the published literature meant the development of an evidence matrix and geographic map of included studies (as proposed in the protocol) was not possible. Instead we provided a narrative assessment of the available literature, gaps in our current state of knowledge and suggestions for how to fill these.

Procedural independence was managed by excluding co-authors with publication records in systematic conservation planning (MCM and RLP) from the screening process.

Results

Primary findings

In total, 15,054 results were retrieved from the 29 sources searched, including 5,228 duplicates (Figure 4.3; details in Additional File 4.1). A further 232 previously unscreened articles were screened based on forwards and backwards citation searches of the included studies (Additional File 4.3). After duplicates were removed, a total of 10,058 articles were screened by title, 5,221 by abstract and 1,209 by full-text. Of those included for full-text screening, 236 were either not in English or not accessible (Additional File 4.4). Where neither hard copy nor digital copies were found through Oxford University's Bodleian Library or Google searches, digital copies were requested from authors via ResearchGate.net. Most of the remaining search results unavailable by full-text had incomplete citation details or were conference abstracts without associated full-text publications.

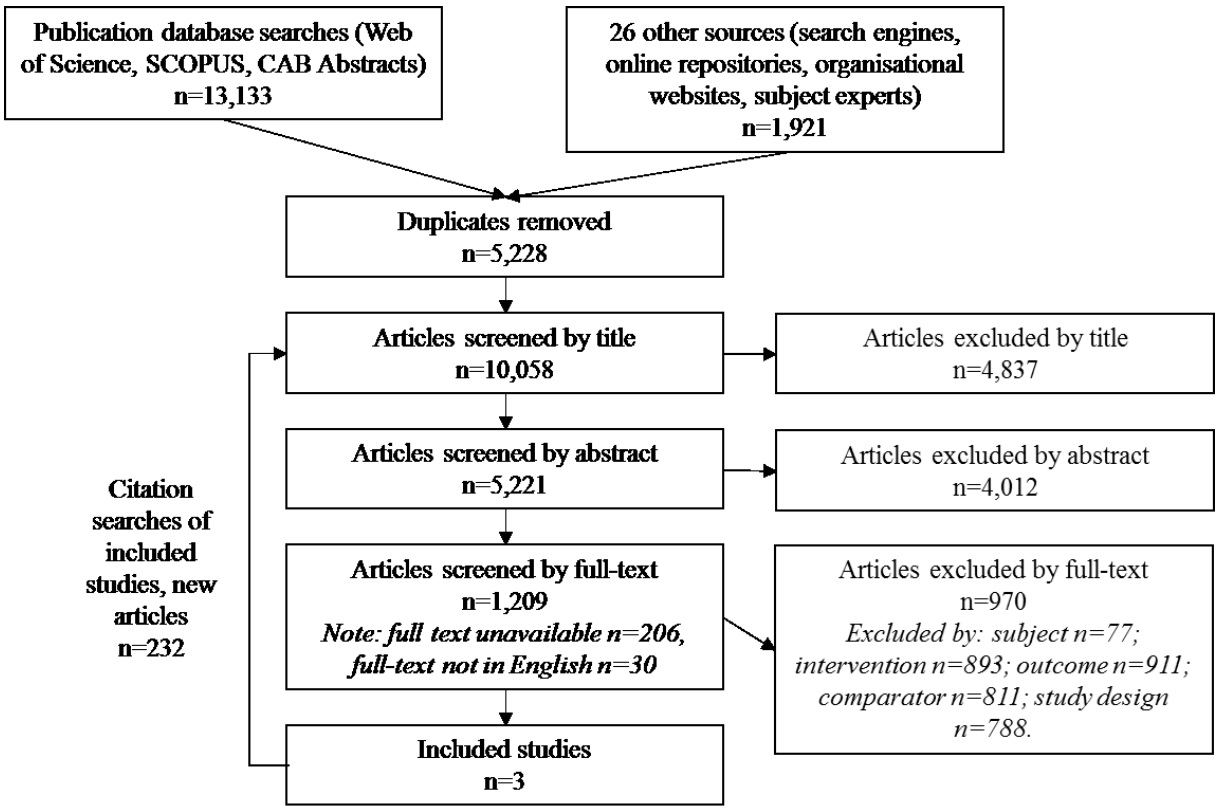

Figure 4.3: PRISMA diagram (Moher et al. 2009) outlining outcomes of articles at searching and screening stages. Articles excluded by full-text were often excluded based on multiple inclusion/exclusion criteria, hence values exceed the total of 970 excluded full-text articles. SCP: systematic conservation planning.

Reasons for the exclusion of the remaining 970 articles were recorded (Additional File 4.5). Seven articles were excluded outright because they were marked as reviews of systematic conservation planning evaluations (Additional File 4.6). If an article was excluded on one or more inclusion/exclusion criteria (Table 4.5) it was not included. All criteria were assessed, and most articles were excluded based on multiple criteria (Figure 4.3). 893 articles were excluded on intervention, 186 of which were deemed "intervention is similar to, but not systematic conservation planning", meaning they were either solely spatial conservation prioritisations (a computational component of systematic conservation planning), or approximated the stages involved in systematic conservation planning but did not involve the spatial conservation prioritisation stage (McIntosh et al. 2016).

Of the 69 studies included on subject and intervention (representing a systematic conservation planning intervention at a relevant scale, Table 4.5), 23 were excluded on outcome because they reported on the design and implementation of a systematic conservation plan but did not provide any details about consequences. In some cases, for example, at the time of publication it was too early to report whether the plan was implemented. This left 43 articles included on subject, intervention and outcome but excluded on study design and comparator. Only three articles were included based on all criteria (Additional File 4.7). One of these had been provided by a subject expert and the other two had been retrieved through publication database searches. One of the included articles reported on multiple different types of planning instances, but we extracted three relevant studies across the three articles.

Additionally, 142 articles were included on subject, study design and comparator but excluded on intervention and outcome, all of which related to formal evaluations of environmental management interventions, but not systematic conservation planning specifically.

Robustness of existing evidence

Coded data extracted from the three included studies is presented in Table 4.6 according to a standardised data coding template (Additional File 4.2). These impact evaluations were undertaken by NGOs and universities. In two studies, the same organisations undertook the evaluation as had developed the plan(s) in question.

Table 4.6: Details of included studies according to a standardised data extraction form (Appendix 4.2).

Category	Included study		
General information			
Publication ID	32732910	27951807	27939613
Source retrieved from	Subject expert	Google Scholar; Web of Science; Scopus; CAB Abstracts	CAB Abstracts
Bibliographic information			
Publication type	Journal article	Journal article	Journal article
Author (s)	Fisher, Jonathan R. B.; Dills, Benjamin	Álvarez-Romero, Jorge G.; Pressey, Robert L.; Ban, Natalie C.; Torre-Cosío, Jorge; Aburto-Oropeza, Octavio	Lagabrielle, Erwann; Botta, Aurélie; Daré, Williams; David, Daniel; Aubert, Sigrid; Fabricius, Christo
Title	Do private conservation activities match science-based conservation priorities?	Marine conservation planning in practice: lessons learned from the Gulf of California	Modelling with stakeholders to integrate biodiversity into land-use planning - Lessons learned in Réunion Island (Western Indian Ocean)
Journal or Publication title	*PLoS ONE*	*Aquatic Conservation: Marine and Freshwater Ecosystems*	*Environmental Modelling & Software*
Publication year	2012	2013	2010
Volume/edition	7(9)	23	25
Publisher	PLoS ONE	Wiley Online Library	Elsevier
Page numbers	e46429	483–505	1413-1427
Basic information about the conservation plan			
Primary region of assessment	National	Sub-national	Sub-national
Country (s) of assessment	United States of America	Mexico	France
Location of study (region)	United States of America	Gulf of California	Réunion Island
Location of study (GPS coordinates)	37.0902400, -95.7128910	27.4803504, -112.0303160	-21.1203276, 55.5483399
Name of resultant protected area network or similar	NA	NA	NA
Name of the planning process	Ecoregional Assessments	Ecological Regional Assessment (ERA)	No name, parallel to the Schéma d'Aménagement Régional (SAR), a regional land use planning process
Type of organisation leading the planning process	NGO	NGO	NA
Planning domain area (km2)	Not provided	361,375	2,512
Type of biome(s)	Terrestrial	Marine	Terrestrial
Start of planning process (year)	1990s	Unclear	Unclear
Duration of planning process (years)	20	Unclear	Unclear
Type of plan (intervention category)	Identify priority conservation actions	Identify priority conservation actions	Identify priority conservation actions

Primary conservation status of area (IUCN category)	Not provided	Not reported/not applicable	Not reported/not applicable
Vision statement	"The priority areas are developed with the intent of representing all relevant biodiversity features in the ecoregion by identifying many individual species, communities, and ecological systems to serve as the targets of planning efforts... The intent is that if protected, the priority areas should represent functional landscapes that ensure the persistence of the conservation targets..."	From Álvarez-Romero et al. 2013 Appendix 1: "Biodiversity conservation and natural resource management: Promote a regional focus in marine coastal conservation and management; provide a detailed portfolio of priority areas that represent the diversity and distribution of species, natural communities, and ecological systems of the ecoregion. Also, contribute to the knowledge of biodiversity of marine and coastal environments, and facilitate the definition and implementation of conservation strategies."	"In line with the current and future development challenges in Réunion Island, the operational objectives of this study were (i) to identify priority areas for conservation, (ii) to provide guidelines for implementing conservation actions outside existing reserves while dealing with increasing pressuring factors in the lowlands; (iii) to "accompany" the conservation sector to negotiate land-use planning and , more particularly in relation to the new regional land-use plan and the management plan of the National Park, and (iv) to explore alternative scenarios for land-use and conservation planning."
Broad objective(s) of the planning process	Biodiversity; ecological processes; species persistence	Biodiversity; ecological processes; fishing; species persistence	Agriculture, aquaculture; biodiversity; ecological processes; economic sustainability; forestry; restoration priorities; species persistence; urban development
Level of stakeholder participation in planning	Not provided	Consulted	Consulted; negotiation
Academic goals	No	Prioritising/comparing actions; zoning/marine spatial planning/land/water use planning; scheduling; implementation	Incorporating socioeconomic costs/objectives; incorporating social/cultural values; incorporating ecological processes; incorporating ecological connectivity; incorporating threats; prioritising/comparing actions; zoning/marine spatial planning/land/water use planning; stakeholder identification/engagement
Type of process/actions considered in planning	Land/Water Protection	Land/water protection; external capacity building	Land/water protection; livelihood, economic & other incentives
Cost of the planning process (prior to implementation)	Not provided	Not provided	Not provided
Tool name	Not provided	Marxan	Marxan; CLUZ
Information on study design (evaluation)			

Methodology type (study design)	Non-experimental	Non-experimental	Qualitative
Method of attribution	Correlational	Correlational	Researcher inference
Overview of the methodology	"The lands acquired by The Nature Conservancy (TNC) were analysed using GIS to determine to what extent they were in areas defined as priorities for conservation."	Seven plans conducted in the Gulf of California were compared and experts were asked to assess their outcomes based on a standardised questionnaire. "...The similarities and differences between planning exercises were examined in terms of data, methods and outputs, how identified priorities match the existing MPA system, and whether plans have guided conservation and management actions."	The evaluation approach was largely reflexive, comparing planning sequences 2 (involving Marxan) and 3 (involving model co-creation with stakeholders), and based on "observations made by the participatory modelling investigators during and 12 months after the process". The authors considered the "researcher's posture in the participatory modelling process" and therefore attempted to recognise potential biases.
Outcomes			
Reported outputs	Policy or plan	Policy or plan; academic paper(s)	Policy or plan; academic paper(s)
Types of outcomes by capital	Institutional	Social; human; institutional	Financial; social; human; institutional
Reported outcomes of planning process	Influence on future decision making by organisation or partners; integration of priorities into policies, conventions or legislation; protected areas expanded	Coordination between different actors; raised awareness of biodiversity or conservation; new knowledge of ecological or social values; learning applied in future plans; influence on future decision making by organisation or partners; role of implementing agency; protected areas expanded	Transparency in conservation investments; coordination between different actors; trust in the planning process; sharing datasets between agencies; attitudes of stakeholders; raised awareness of biodiversity or conservation; new knowledge of ecological or social values; learning applied in future plans; influence on future decision making by organisation or partners; consideration of conservation issues in decision making by other sectors
Direction of change of outcome	Unclear	Positive	Positive
Did the project outcomes reflect achievement of the original plan vision statement?	Not provided	Yes	Yes
Context of study (evaluation)			
Location of lead author's organisation (country)	United States of America	Australia	France
Type of organisation leading the evaluation	NGO	University	University
Is the lead organisation the same as that which originally conducted the planning process?	Yes	No	Yes

Purpose/rationale for the study (stated reasons for undertaking an evaluation)	"The Nature Conservancy (TNC) and other large conservation organisations have invested substantial resources in developing conservation plans intended to guide their decisions about which land areas and bodies of water to conserve. However, despite the investment in developing a scientific method for prioritising areas for conservation, the degree to which land acquisition actually follows these scientific priorities has not been investigated before now."	"While theory in conservation planning is developing quickly, there has been no assessment of the influence of new ideas on applications of marine conservation."	"...the overall goal was to test different approaches to bridge the scientific and operational communities by bringing multidisciplinary scientists and stakeholders to collaborate around the participatory development of spatial models for land-use and conservation planning."
Hypotheses of evaluators	"Our first hypothesis was that overall the acquisition of lands should be well aligned with priority areas on the assumption that TNC chapters base their acquisition decisions on the best available conservation science. We did not expect perfect alignment for several reasons noted in the discussion section. Second, we hypothesized that there would be improvement over time in the match between science-based priorities and land protected by TNC as assessments and planning methods were increasingly formalized and improved. Our third hypothesis was that outright fee simple acquisition of land would show greater alignment with the priority areas than procuring conservation easements."	Not provided	Not provided
Outcome pathways			
Theory of change or conceptual model (for how the plan was expected to lead to intended outcomes) included in the study?	No	No	No

Fisher and Dills (2012) reported on ecoregional assessments conducted across the USA, which were based on systematic conservation planning principles (The Nature Conservancy & World Wildlife Fund 2006). The authors explored the relationship between terrestrial areas

prioritised for biodiversity conservation by an environmental NGO (The Nature Conservancy, TNC), and those acquired for protection by the NGO over several decades.

Lagabrielle et al. (2010) outlined a terrestrial planning process for the island of Réunion which was conducted in parallel with the revision of a regional development plan. The evaluation approach was largely reflexive, comparing a planning attempt involving systematic conservation planning (which they referred to as sequence 2) and another where agent-based modelling and companion modelling were used to explore future land-use change scenarios (sequence 3).

Álvarez-Romero et al. (2013) compared seven marine conservation planning exercises undertaken over a 15-year period in the Gulf of California, Mexico. One of these plans met our definition of systematic conservation planning (the Ecoregional Assessment (Ulloa et al. 2006)) and it alone is the relevant study discussed here. Experts on regional marine conservation issues were surveyed and asked to identify planning goals, the extent to which these were achieved and how planning outputs influenced implemented conservation actions.

Characteristics of the current evidence base

Two studies were conducted at subnational scales and one nationally. The areas of interest ranged from 2,500 km^2 to over 300,000 km^2. Two studies concerned the terrestrial realm and one marine. We classified all three intervention types as aiming to 'identify priority conservation actions'. None were intended for direct application. The objectives of all studies included biodiversity, ecological processes and species persistence and two also included other considerations, such as fisheries, agriculture and urban planning. Stakeholder engagement most commonly involved consultation, and in one instance also negotiation. The duration of the planning processes and associated costs were unclear in all three studies.

Types of outcomes of systematic conservation planning exercises

All included studies reported institutional outcomes, two also reported on social and human outcomes, and only one reported any financial outcomes. None reported natural capital outcomes. Examples of outcomes included sharing of knowledge between stakeholder groups and a greater awareness of the complexity of urban planning amongst participants (Lagabrielle et al. 2010) and influence of the planning process on future decision making by the organisation or partners (Fisher & Dills 2012; Álvarez-Romero et al. 2013). Two of the three studies reported on whether the project outcomes reflected achievement of the original plan vision statement, and both reported the vision had been achieved.

Types of study designs used in evaluations of systematic conservation planning

None of the studies provided theories of change or a discussion of how they expected the plans to lead to potential conservation (or other) outcomes. Only one stated a hypothesis for the evaluation. Two studies involved non-experimental study designs where the method of attribution was correlative. The other was qualitative, and attribution was based on researcher inference.

Review of our search methodology

One of the included studies (Fisher & Dills 2012) originated from the call to subject experts, but unlike the other included studies, had not been returned in the searches of publication databases (all included studies had been published in indexed journals). To explore the reasons for this, a review of the original search string was conducted in Web of Science Core Collections on 24/01/18 (Additional File 4.8). This confirmed the intervention and outcome search terms were appropriate, but the subject terms were not sufficiently diverse. By adding the term 'protection' to the subject terms, the missed article (Fisher & Dills 2012) was returned in the new search, along with 342 additional articles compared to the original search string

(excluding a further 563 articles added to Web of Science in the 11 months since the original search). This finding can be used to help better design future searches (see Discussion). However, the 342 studies were not screened for relevance and none were included in the study since we would for parity necessarily have to have to repeated searches across all 29 sources beyond the original March 2017 cut off.

Discussion

Faced with prioritising limited resources for biodiversity conservation, conservation planners are increasingly turning to systematic conservation planning tools and techniques. Their aims are to explore financially and socially acceptable trade-offs, whilst seeking to optimise representation and, usually implicitly, the persistence of species and habitats (Kukkala & Moilanen 2013). In this study, we collated articles on the application of systematic conservation planning and the outcomes of related plans. The aim was to assess the evidence base rather than produce meta-analyses or detailed syntheses. Despite retrieving over 10,000 articles from traditional academic and grey literature sources, only three studies were found to contain robust evaluations of this extensively applied intervention type and none that reported evaluation of natural capital outcomes. This highlights an important evidence gap, particularly given the amount of interest in systematic conservation planning and the significant cost of undertaking plans (Bottrill & Pressey 2012). This is a null result, rather than a negative finding and was not completely unexpected, given the barriers to undertaking evaluations of complex interventions (Curzon & Kontoleon 2016). As stated in our original protocol, "a finding that no or few impact evaluations have been undertaken on systematic conservation plans would highlight an important gap in evaluations of the technique to date" (McIntosh et al. 2016: 4).

Rigorous Collaboration for Environmental Evidence guidelines (CEE 2013) were used to identify three relevant studies, that provide valuable insights into how plans are conducted and how outcomes can be interpreted. However, the studies did not conform perfectly with our inclusion criteria, particularly in relation to comparators and study designs. The below considerations highlight the difficulties of interpreting studies of planning interventions, as well as the prevalence of incomplete records and challenges when attributing outcomes to complex interventions.

Contrasting evaluation methodologies

The three included study designs differed greatly and demonstrated the importance of understanding regional contexts and of interpreting results with care.

Fisher and Dills (2012) undertook a meta-analysis, the assessment of a planning campaign over several decades, rather than assessments of individual plans and the causal processes that led to the outcomes of those plans. The authors were not able to provide conclusive evidence that systematic conservation planning influenced land acquisition decisions, but this finding masked the complexity underlying the value of the formal ecoregional assessment processes. While they did find that the land acquisition patterns by TNC were positively correlated with priority areas in all states across the USA, no difference was observed in land acquisition patterns before and after systematic ecoregional assessments were implemented.

Rather than a before/after analysis, Álvarez-Romero et al. (2013) compared seven different approaches to planning in a single region, five of which approximated systematic principles although only one met our definition of systematic conservation planning. The plans overlapped spatially and temporally to some degree, and the authors employed both quantitative and qualitative data collection methods. The six plans that did not meet our definition of systematic conservation planning are not ideal counterfactuals for the relevant plan given that datasets and experiences from earlier plans often influenced subsequent planning processes. Furthermore, these plans were not explicitly contrasted to the relevant plan in the results, as data were aggregated across all seven plans. Use of a survey methodology facilitated an assessment of how goals, outcomes and spatial areas recommended for protection differed between the seven plans. Surveying people one step removed from the plans in question provides an example of how to limit bias when reporting on planning outcomes.

The third included study by Lagabrielle et al. (2010) was considered borderline in terms of constituting a qualitative study design in part because it directly reported on the opinions of the authors, with little explanation of causal links or justifications for reported outcomes. We included it because the authors considered the "researcher's posture in the participatory modelling process" (Lagabrielle et al. 2010: 1425) and therefore attempted to recognise potential biases. They provided thoughtful reflections on the scientists' role in the process, and comparisons between the experience of conducting a systematic conservation planning study using Marxan, with a process where stakeholders co-created models and planning outputs with scientists.

Another article we screened, by Carter et al. (2014), provides a valuable example of how to conduct an evaluation of the outcomes of conservation plans, even though it was not included (it was excluded by intervention type as it was not SCP). The authors quantified land management actions (i.e., changes in the amount, location and land cover type of protected areas) in relation to individual state land management plans in Wisconsin, USA. They found that land protection activity increased in prioritised regions after plans were released, an effect that was high for local land protection projects but weak for broader, state-wide plans (a finding consistent with that of Fisher and Dills (2012)). They also noted that most actions occurred within the first five years after a plan was released and decreased over time. Two plans discussed in this article were similar to systematic conservation plans but were excluded on intervention and outcomes. It remains an insightful article, exploring the causal pathways by which plans may influence conservation actions.

Overall, we identified 43 studies with relevant subjects, interventions and outcomes, but which we were unable to include due to unsuitable study designs and comparators (Additional File 4.2). In general, the evaluation strategies were not sufficiently rigorous for inclusion, or to independently verify claims. This is not uncommon in studies of environmental interventions

(Ferraro & Pattanayak 2006; Morandi et al. 2014). Despite suggestions that conservation experts are unaware of how to conduct high quality evaluations (Ferraro & Pattanayak 2006), recent research suggests the main barriers to undertaking such studies relates to a lack of funding and time constraints, as well as availability of baseline data, lack of forward planning, and availability of a suitable control group (Curzon & Kontoleon 2016).

Four studies were excluded by comparator only (Pressey et al. 2002; Fernandes et al. 2005; Nutters & Pinto da Silva 2012; Bottrill et al. 2012). Authors of similar systematic maps have occasionally been flexible on screening by comparator (Sola et al. 2017), noting it is particularly unusual and challenging to employ use of comparators in multidimensional interventions such as planning. Instead we have been clear about the fact that our included studies do not perfectly match the inclusion criteria and list our reasons for exclusion (Additional File 4.5).

Lack of clarity around intervention definitions

The plans underlying all three included studies varied in the degree to which they met our definition of systematic conservation planning. For example, in Fisher and Dills' study (2012) the methods underpinning TNC's ecoregional assessments (The Nature Conservancy & World Wildlife Fund 2006) draw heavily from the systematic conservation planning literature. The use of spatial conservation prioritisations and computational decision-support tools is promoted by TNC, but is not mandatory, in contrast to our definition of this intervention (Table 4.5). We were not able to determine what proportion of ecoregional assessments in the included study involved the use of computational tools, and the authors acknowledged this type of information was not always available.

Very few full-text articles met our specific definition of systematic conservation planning (n=80). Our definition is heavily drawn from the academic literature and may be better

interpreted as a set of guidelines, rather than a distinct intervention. Groves and Game (2016a) recommend that conservation planners decide on which tools to include within a planning process depending on their specific needs, available funds and teams' skill sets. It appears that this is a better representation of how planning processes are conducted in practice than the 11-step framework we used to help define the intervention (Figure 4.1). The latter may be better interpreted as a list of components from which planners pick and mix. However, expanding a study of this nature to include all conservation planning studies that are systematic to some degree would introduce high levels of variation, making comparisons extremely challenging.

For these reasons, it may be appropriate to review strict definitions of systematic conservation planning, including our own. Alternative conceptualisations of conservation planning as an intervention may be required. In addition, research is warranted on the relative benefits and limitations of following some, rather than all, planning stages of outlined in Figure 4.1.

Predominance of publications on prioritisations rather than planning

This systematic map illustrates how rarely evaluations of systematic conservation plans are published. Yet, despite their novelty, none of the three included studies was published in the most common journals associated with the discipline. According to a review conducted in 2012 (Kukkala & Moilanen 2013), the three journals with the greatest number of articles on systematic conservation planning are *Biological Conservation, Conservation Biology* and *Biodiversity and Conservation*. Citation searches in Google Scholar revealed our three included studies have been cited between 18 and 65 times over the five to eight years they have been in publication. This is low in comparison with a seminal paper on systematic conservation planning, cited over 4,500 times since 2000 (Margules & Pressey 2000).

Our results corroborate claims that the literature on systematic conservation planning is dominated by methodological studies, rather than those that focus on implementation and

outcomes, and support the case that this is a problematic imbalance in the literature (Knight et al. 2008). Spatial conservation prioritisations made up the majority of the 186 studies we marked as “intervention is similar to, but not systematic conservation planning”. These were generally undertaken as hypothetical exercises or to propose a methodological innovation, rather than being linked to a broader planning and implementation strategy. Given estimates of the number of published prioritisations (e.g. 160 in the marine realm alone (Álvarez-Romero et al. 2018)), our finding of 186 related studies is lower than expected. This may be because we included evaluation terms in the search strings and excluded articles that were clearly only spatial prioritisations at the abstract screening stage.

Several authors acknowledged that they specifically decided not to conduct spatial conservation prioritisations as part of their (otherwise systematic) planning processes (Baskent et al. 2008; Kirlin et al. 2013). Kirlin et al. explained “this technique [use of Marxan software] was explicitly rejected in the initiative as inconsistent with the legal requirements... regarding network design and not sufficiently transparent to policy makers or stakeholders" (Kirlin et al. 2013 p. 4). Lagabrielle et al. (2010) also stated that they had to abandon a planned aspect of stakeholder consultation alongside their development of prioritisations in Marxan because “...this tool embeds strong hypothesis about land-use management and conservation, such as, for instance, the attribution of a value to biodiversity features. The participants globally disagreed with this approach and thus rejected the tool” (Lagabrielle et al. 2010 p. 1424).

Another insight revealed in this study was the high number of plans that focused on reporting the representativeness of protected area networks (or similar) rather than measures of species’ persistence or other measures of impact (and therefore had to be excluded). A protected area network might contain representations of each habitat type, but still fail to ensure species persistence, perhaps because of the inadequate size of, or connectivity between, habitat patches or inadequate representation of the habitats most in need of protection (Pressey et al. 2017).

Too narrow a focus on representativeness in systematic conservation planning risks plans failing to secure healthy populations and species as intended.

Comparison with related reviews of systematic conservation planning

In a recent survey, conservation planning practitioners reported much higher rates of plan implementation and downstream outcomes than is observable in the published literature (Sinclair et al. 2018). This finding is supported by unpublished outcomes provided by the lead author of one of the included studies "Our research worked so well (in terms of impacts) that I was recruited at the university of Réunion Island and the PhD co-student I worked with... is now in charge of developing and monitoring official regional land-use and risk management plans for the Regional Councile of Réunion Island" (Personal communication, Erwann Lagabrielle via email; 4 December 2017). Following up related studies (like Lestrelin et al. (2017) in this case) can also indirectly demonstrate how institutional approaches to planning and stakeholder participation evolve following a systematic conservation planning exercise and how new knowledge and data can benefit subsequent decision-making. However, it is often necessary to ask authors which studies are directly linked.

In contrast to a recent review on the same topic (Wiersma & Sleep 2016), albeit more limited in scope, our results suggest there is insufficient evidence to claim whether systematic conservation plans are or are not achieving conservation goals. Through application of rigorous systematic mapping methods, we identified two relevant terrestrial studies which the authors of that review did not appear to locate. However, we concur that more detailed examinations of how plans are implemented in specific regions would be useful and reaffirm statements made by Bottrill et al. (2012), "Empirical evidence is not available to support the belief in the benefits of planning".

Other systematic maps and reviews in the environmental sciences have also reported few or no relevant studies, despite also focusing on widely applied, and well-funded disciplines (Bowler et al. 2012; Da Silva et al. 2016; Bayliss et al. 2017). It is important to share such results to illuminate knowledge gaps, limitations with study quality and to avoid duplicating enquiries or assumptions (Alderson 2000).

It is useful for practitioners and decision makers to know when an intervention has not been evaluated to support claims of effectiveness. However, the lack of a consensus on the outcomes of systematic conservation planning does not imply there is no evidence at all. Evidence can take multiple forms, including anecdotal observations from subject experts. For example, the 43 studies which reported the outcomes of systematic conservation planning interventions but which did not meet our rigorous inclusion criteria for study design and/or comparator (Additional File 4.7) are still valuable to decision makers (Greenhalgh & Russell 2006). Examples of anecdotal outcomes included; "…the initial conservation planning map… has already been used…to block proposed afforestation permits that would have destroyed an area of high conservation value…" (Smith & Leader-Williams 2004 p. 10), and "…pooling of resources, expertise, and capabilities was one of the enabling features in delivery of the new zoning plan…" (Fernandes et al. 2005 p. 1742).

Limitations of the map

Comprehensiveness of search

The three included studies were located from different sources, reinforcing the importance of a multi-pronged strategy. The fact that experts in the field confirmed they were not aware of other published studies provided further support for our results (Additional File 4.1). Therefore, we doubt the inclusion of additional sources, non-English publications or contact with more subject experts would have made a major difference to our results.

A test library of eight studies we had expected to be included was used in the design and testing of the search string (Additional File 1 in the protocol (McIntosh et al. 2016)).This test library was also used to test the comprehensiveness of the search results returned after sources were searched and duplicates removed. Six of the test library articles were returned by our searches, two were not. One was an organisational report (Raab 2006) so does not appear to have been accessible through the grey literature sources we searched. The grey literature is necessarily harder to search (e.g. some databases we hoped to include did not facilitate the mass exporting of search results, Additional File 4.1). The other test library article (Gelderblom et al. 2003) appears to have included subject terms other than those in our search string (this issue is addressed further below).

Future revisions to this search strategy should consider broadening the search string. A keyword we recommend for inclusion is 'ecoregion' or 'ecoregional assessment', a term used by The Nature Conservancy to encompasses systematic conservation planning. These terms were trialled and not included in the search strings because they did not initially appear to contribute additionally to search results. Many ecoregional assessments were returned through our searches, but others may have been missed.

Limitations with our chosen subject terms apparently arose from the discipline of systematic conservation planning being relevant to a diverse array of subjects. Without significantly expanding the subject search terms to include a potentially limitless spatial terms (e.g. 'protection', 'natural resource', 'forest', 'pasture' and so on), relevant studies may be missed. Excluding the qualifier search terms also works to broaden the results, but a careful balance is required to avoid returning too many irrelevant search results.

There is a small risk that literature that does not conform with the academic jargon around systematic conservation planning was overlooked during screening. However, our inclusion

and exclusion criteria (Table 4.5) were specifically designed with this risk in mind, focusing instead on key characteristics of plan design and implementation.

Efficiency in the review process

During the process of conducting this review we experimented with various technological approaches to increase the efficiency of screening thousands of articles. This included trialling specialised software to manage the screening process (Kohl et al. 2018). Automated duplicate checking, and web scraping also led to significant time savings. Despite progress in the use of machine learning to help automate abstract screening (O'Mara-Eves et al. 2015; Gates et al. 2018), we concluded this technology is not sufficiently developed to have been applicable without further testing. Innovative methods are much needed, particularly as the size and scope of maps and reviews continue to increase (Cheng et al. 2018; Westgate et al. 2018).

Conclusions

Implications for policy and management

The lack of rigorous evidence for the impacts of systematic conservation planning is of considerable concern. Additional studies are urgently needed to understand the work of governments and environmental NGOs applying these methods around the globe. A strong assumption from theory is that systematic conservation planning is more effective at conserving species and habitats than alternative approaches to allocating resources for conservation (be they *ad hoc*, driven by extractive use considerations, or based primarily on stakeholder negotiation). Given the focus on evidence, it is consistent with the epistemology of the discipline to ask whether there is evidence for effectiveness, and to suggest ways in which such evidence might be made more easily available. However, there are many theoretical and practical reasons to believe systematic conservation planning is preferable to alternative approaches (or doing nothing) (Barnes et al. 2018). The race is on to protect sufficient areas of

the land and ocean, increasing the importance of core systematic conservation planning principles like representation of species and habitats, clear objective-setting and well-designed stakeholder engagement (Venter et al. 2017).

Implications for research

In this study, we confirmed a growing evidence -base for the suitability of different methodological approaches for spatial conservation prioritisations (Hermoso et al. 2012; Klein et al. 2013). We also found some evidence of how systematic conservation plans are being implemented, including lessons learnt (Smith & Leader-Williams 2004; Brownlie et al. 2005; Reyers et al. 2007; Pressey et al. 2013). However, rigorous impact evaluations are lacking. A full set of guidance is likely beyond the scope of this study, but some recommendations are provided below.

To improve the quality of future evaluations of conservation plans, we suggest conservation planning organisations provide incentives and time for staff to write up their findings and make them publicly available (even if not in an academic journal). In addition, conservation planners and academics would benefit from collaborations to leverage the additional resources and skills required to complete evaluation studies. Long-term ecological monitoring and reporting combined with adaptive management (Westgate et al. 2013) and standardised metrics of management effectiveness (Hockings 1998; Geldmann et al. 2018) are extremely valuable. More examples of ways to improve evaluation in systematic conservation planning are offered by McIntosh et al. (2017; Paper 1 - see pages 51-53).

To improve project documentation, we suggest including: a) explicit statements about the objectives of a systematic conservation planning process and quantitative or qualitative evidence for whether those objectives were met; and b) detail about the intervention i.e., how the planning process was conducted, to enable readers to determine whether the process has

the attributes of a systematic conservation planning project. To improve evaluation documentation, we suggest including: a) theories of change about how specific aspects of the planning process were expected to lead to particular outcomes (and where possible, whether results led to a modified understanding of the theory of change); b) clear descriptions of the study design (with reference to existing classifications e.g. experimental or qualitative sampling (Margoluis et al. 2009)) and discussion about any limitations with the chosen study design; and c) where possible, presentation of a range of perspectives on the outcomes and potential causal links with the planning process.

When designing an evaluation in these contexts, it is preferable to focus on improving the minimum standards of evaluation, rather than expecting to achieve 'best practice' evaluation methodologies (Smith & Pell 2003; Curzon & Kontoleon 2016). Based on our included studies and related literature on barriers to evaluation (Curzon & Kontoleon 2016), the most practical counterfactual study designs for conservation planning are likely to include comparisons before/ after the planning process. As a minimum, authors should identify potential alternative explanations (external to the planning process) for observed outcomes and explain their understanding of the relative importance of different potential causal processes. Examples include stakeholder perceptions of the relative importance of a local election in promoting political action, or a natural disaster having reduced interest in planning versus on-ground action. For more see Paper 1 / McIntosh et al. (2017). Given that systematic conservation planning constitutes a form of 'dynamic planning' (Pressey et al. 2013), dynamic approaches to evaluation may also be necessary. This could include elements of development evaluation, where an evaluator is integrated with the design team (Patton 1994).

These styles of studies are not impossible to undertake or report on. An increased uptake of before-after and with-without designs in the conservation policy field has been reported by conservation experts (Curzon & Kontoleon 2016). In one of our included studies, a temporal comparator was employed using historical land ownership records. This type of analysis is

likely to be feasible in many conservation planning scenarios, particularly where the use of experimental study designs and controls would not be cost effective or ethical.

During full-text screening we encountered several interesting study designs and uses of comparators that have been undertaken in related disciplines. For example, qualitative case study evaluations compared different planning approaches in a single region (Lagabrielle et al. 2010; Gleason et al. 2013), and another compared two neighbouring regions, one that participated in a community zoning project, and another that did not (Leisher et al. 2011).

In the short term, it is unlikely that enough new studies will be produced to warrant a revision of this systematic map. Future research may consider exploring the evidence for the effectiveness of specific aspects rather than evaluating systematic conservation planning in its entirety (e.g., stakeholder attitudes of consultation processes).

Overall conclusion

Remarkably few rigorous evaluations of systematic conservation plans have been conducted to date, despite many claims about their effectiveness. This does not imply systematic conservation planning is, or is not, effective, but highlights the gap in our understanding of how, when and why it may or may not be effective. It also raises important questions about the challenges of conducting rigorous evaluations in relation to a non-linear and multi-dimensional intervention such as conservation planning. We have provided some suggestions as to how these challenges can be overcome. We recommend more focus is required in this area. We urge academics and practitioners alike to publish the results of systematic conservation planning exercises and to employ robust evaluation methodologies when reporting project outcomes.

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files, which will be made available for download from the *Environmental Evidence* website.

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5

Paper 5: Barriers to the evaluation of systematic conservation plans: Insights from landmark Australian plans

This paper has been submitted as a research article to *Biological Conservation.*

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Abstract

The evaluation of conservation programs is often inhibited by barriers such as lack of funding and time constraints. Through an exploration of two internationally influential systematic conservation planning activities conducted in Australia in the 1990s and 2000s I demonstrate this is also true for conservation planning. Forestry agreements in North East New South Wales and the rezoning of the Great Barrier Reef Marine Park popularised the now widely used planning software packages C-Plan and Marxan. Through 37 semi-structured interviews with senior stakeholders involved in decision making around both plans, I examined barriers to evaluation, the factors underpinning these barriers, and, in the absence of impact evaluations, stakeholder perceptions of the effectiveness of the plans. My findings confirmed that the primary barriers to the evaluation of conservation planning exercises are: a lack of suitable monitoring data, resource limitations and inadequate preparation. Respondents also shed light on the factors which shaped these barriers, in a conservation context, such as the need for political expediency, a loss of momentum post-plan, and the presence or absence of necessary leadership. Perceptions of the effectiveness of the plans reflected interpretations of a) whether the planning process followed good practice, b) the fact a planning result was agreed upon and implemented, c) the longer-term influence of the plan, and, in contrast to much of the current literature on these case studies, d) the consequences of industry restructuring.

Highlights

- Barriers to evaluation were due to lack of resources and preparation
- Political context and organisational culture shaped barriers to evaluation
- Healthcare and other disciplines face similar challenges and can offer lessons
- New perspectives on project effectiveness are shared from senior decision-makers
- Perceptions of effectiveness also reflected the effects of industry compensation

Keywords

Biodiversity conservation, elite interviews, environmental management, environmental policy, evaluation, planning

Acronyms

GBR: Great Barrier Reef

GBRMPA: Great Barrier Reef Marine Park Authority

NSW: New South Wales

RAP: Representative Areas Program

SAP: Structural Adjustment Package

Introduction

Conservation planning offers the opportunity to adopt a 'prevention is better than cure' approach to environmental policy making. The allocation of resources must be conducted advisedly and transparently if associated decisions are to be supported by affected stakeholders (Adams et al. 2018). Opportunities to shape the future resource use and conservation agenda may only arise once a decade (Pressey et al. 2013). It is therefore important to learn from prior planning exercises, to maximise the efficiency and effectiveness of future conservation plans (Kapos et al. 2010).

Systematic conservation planning is a discipline centred on improving conservation decision making and is a popular approach to designing protected area networks and for prioritising conservation actions (Margules & Pressey 2000; Watson et al. 2011). It is characterised by quantified conservation objectives and provides a platform for stakeholders to discuss the trade-offs associated with potential planning options (McIntosh et al. 2017). Despite the

influence of the discipline, there is a significant gap in the literature on the implementation and evaluation of systematic conservation plans (Knight et al. 2008; Mair et al. 2018). Only three rigorous evaluations of systematic conservation plans have been identified in a recent comprehensive study, meaning that our understanding of how, when and why they may or may not be effective is severely limited (McIntosh et al. 2018). If evaluations are rarely conducted, it begs the question of why, when conservation planning often costs millions of dollars (Didier et al. 2009a; Bottrill & Pressey 2012) and funders would presumably want to understand the value of their investments.

In this study, I interviewed senior stakeholders involved in landmark systematic conservation planning programs in Australia, to understand why impact evaluations of the programs had not been conducted. Some ecological monitoring has taken place in both cases, but neither have been evaluated in their entirety as you might expect for a major policy or program. In the absence of evaluations, I also sought their views on the effectiveness of the planning programs.

Key barriers to evaluation

Program evaluation refers to a process of making inferences about an unobserved counterfactual outcome from a program or policy, i.e. what would have happened in the absence of the intervention (Ferraro & Pattanayak 2006). Best practice evaluation methods can be defined as "methods that account for the counterfactual and are able to attribute causality between a conservation policy and specific observable environmental and social impacts" (Curzon & Kontoleon 2016; 466). This requires a distinction between outputs (e.g. reports), outcomes (the observed or assumed effects of conservation outputs (Pressey et al. 2017)) and impacts revealed through counterfactual analysis (McIntosh et al. 2017).

It has been claimed that conservation science lags behind similar crisis disciplines such as medicine and public health in the provision of high-quality evaluations (Game et al. 2014), and conservation scientists have been called on to improve efforts (Ferraro & Pattanayak 2006;

Ferraro 2009). It is often assumed that the small number of rigorous impact evaluations is primarily due to a lack of interest or knowledge on the part of conservation professionals (Ferraro & Hanauer 2014; Pressey et al. 2017).

Recent work by Curzon and Kontoleon has challenged this assumption (2016). The authors surveyed conservation policy experts to understand the primary reasons why impact evaluations are rarely conducted (Curzon & Kontoleon 2016). Their respondents considered the use of experimental and quasi-experimental program evaluation methods as 'very important or quite important' (95% of respondents) and expressed a desire to conduct these more often (Curzon & Kontoleon 2016). Respondents reported the top five barriers to implementing high-quality evaluations (using such methods) were: lack of funding, availability of baseline data, time constraints, lack of forward planning and availability of a suitable control group (Curzon & Kontoleon 2016). In fact, 78% of participants agreed that the two most significant barriers were lack of funding and time constraints.

Conservation scientists and practitioners are not alone in facing barriers to evaluation. The primary barriers met by third sector organisations in healthcare settings also relate to organisational capacity and capability (Bach-Mortensen & Montgomery 2018). A study of how low carbon community groups in the UK approach monitoring and evaluation found that issues of capacity, resources and utility hampered attempts (Hobson et al. 2016). Participants were aware of the benefits but were wary of getting overly invested, concerned about taking on additional administrative burdens and cautious about interpreting impacts such as behaviour change.

In natural resource management, evaluation has been limited due to the lack of measurable goals and an undue focus on monitoring biophysical or economic performance criteria rather than social or political criteria (Bellamy et al. 1999). When it comes to applying complexity theory in evaluations, a multiplicity of definitions, the dominance of existing approaches,

perceptions of resources required and the purpose of the evaluation can all form barriers to application (Walton 2016). Even in academic circles, such as UK universities, which are now required to include impact in Research Excellence Framework reporting, expertise does not equate to the ability to articulate research impact, nor imply that academics are always prepared to approach impact evaluation strategically (Wilkinson 2017).

Barriers such as these can only be overcome by understanding their causes or 'facilitating factors' (Figure 5.1). These are often out of the hands of conservation practitioners and may be shaped by considerations outside the scope of a particular project. Based on research outside the conservation literature, facilitating factors that help promote evaluation can include: ensuring appropriate support, an organisational culture that supports evaluation, and the motivation to be accountable to stakeholders (Bach-Mortensen & Montgomery 2018). Senior healthcare policy makers commonly raise themes that influence the ability to perform evaluations, such as political influence, financial resources, timelines, organisational culture around evaluation, cautious attitudes to expected results and the skills of relevant staff (Huckel Schneider et al. 2016).

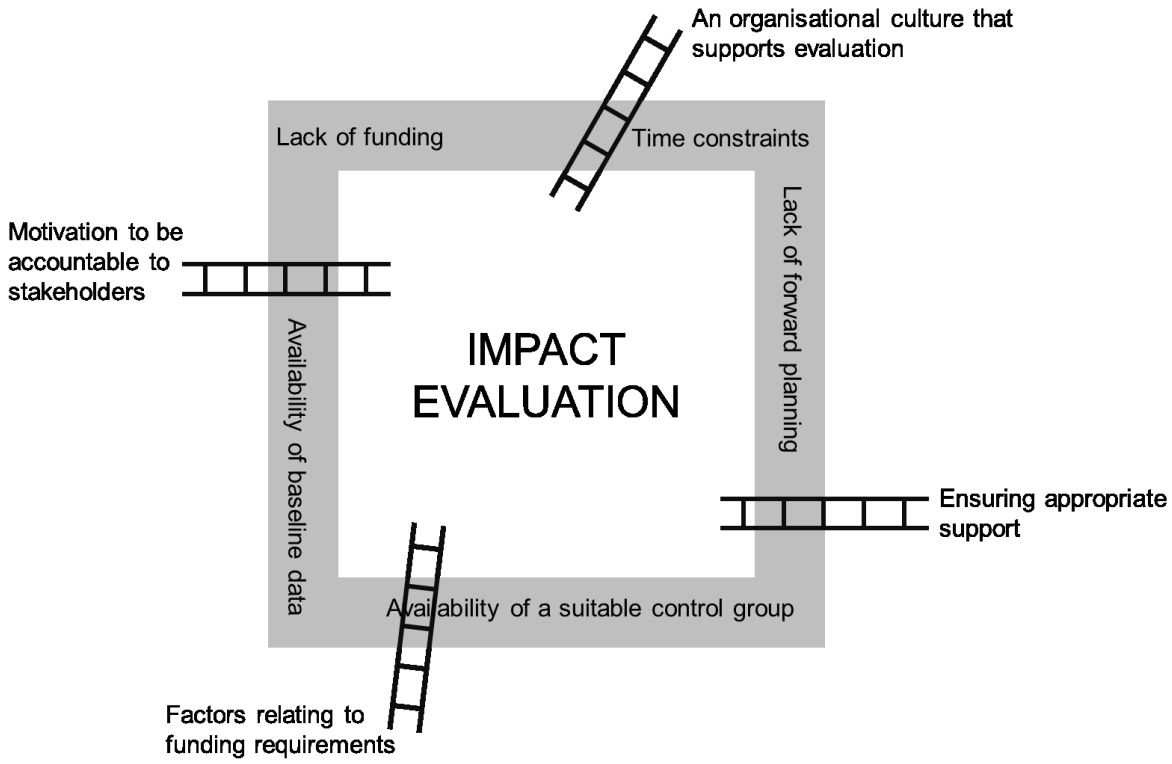

Figure 5.1: Illustration of the relationship between barriers (shaded box) and facilitating factors (ladders) relating to the conduct of impact evaluations (examples drawn from Curzon & Kontoleon (2016) and Huckel Schneider et al. (2016)).

Aims & research questions

I was interested to explore the primary barriers to the evaluation of systematic conservation plans, and the factors influencing these barriers. I selected two case studies of high-profile natural resource planning processes in Australia which were completed over a decade ago. They represent early applications of systematic conservation planning principles and tools and have influenced conservation activities across Australia and around the world. My primary research questions were:

- What barriers were reported as having limited the evaluation of the planning programs?
- What were the inhibiting factors which created these barriers or the enabling conditions which assisted evaluation efforts?

- How were perceptions of the effectiveness of the conservation plans constructed by different stakeholders (in the absence of program-wide evaluations)?

The intent was not to conduct impact evaluations myself, nor to collate all available social and ecological monitoring data as evidence from these case studies. Instead I sought to understand from those most closely involved in decision making, what evidence they are aware of, and how they justify their perceptions of effectiveness.

Systematic conservation planning case studies

In this study I focus on two landmark examples, forest agreements in North East New South Wales and the Great Barrier Reef rezoning.

Forest agreements, North East New South Wales

In the 1980s and 1990s, the 'forest wars' were regular front-page news in Australia, with large scale protests in native forests and logging trucks blockading Parliament House. This precipitated the National Forest Policy Statement (Commonwealth of Australia 1992) and the requirement for states to sign twenty-year Regional Forest Agreements (RFAs) with the Federal (Commonwealth) Government to protect environmental values and promote ecologically sustainable forest management (Department of Urban Affairs and Planning 1999; Davey et al. 2002). Two of the ten national RFAs are the subject of this study: the Upper and Lower North East New South Wales (NSW) RFAs. They stretch between Sydney and the NSW/Queensland border covering an area of almost 100,000 km^2 and contain the Central Eastern Rainforest World Heritage Area. Leading up to the signing of the combined Upper and Lower NE NSW RFA in 2000 (Commonwealth of Australia & State of New South Wales 2000) there was a moratorium on native timber logging in 1996 and an interim assessment process was conducted (Pressey et al. 2002), which kickstarted the use of the planning software C-Plan to help prioritise habitats for protection (Pressey et al. 2009). This was followed by

Comprehensive Forest Agreements in 1999 (Commonwealth of Australia & New South Wales Government 1999), which provided the scientific basis for, and were overridden by, the RFAs. The result was the reservation of over 7,000 km^2 of forest as National Parks, large areas of which were transferred from management by State Forests to the National Parks and Wildlife Service in NSW (Flint et al. 2004).

I refer to 'NE NSW forest agreements' throughout as collectively referring to the interim, comprehensive and RFA processes for upper and lower NE NSW, unless referring to one planning stage or region specifically.

Representative Areas Program and Structural Adjustment Package, Great Barrier Reef Marine Park

The Representative Areas Program (RAP) was undertaken by the Great Barrier Reef Marine Park Authority (GBRMPA) from 1999 to 2004, to re-zone permitted activities in the Great Barrier Reef Marine Park (GBR or 'reef'). Encompassing an area over 340,000 km^2, the marine park falls under both Queensland and Commonwealth government jurisdictions and largely overlaps with the Great Barrier Reef World Heritage Area. At the commencement of the program, approximately 4% of the marine park was closed to fishing in no-take marine zones (called 'green zones'). By the time The Great Barrier Reef Marine Park Zoning Plan 2003 (GBRMPA 2003) was accepted by the Australian Parliament, 33% was in green zones (Fernandes et al. 2005; Day 2016). The previous zoning was primarily focused on coral reefs (Day 2016), therefore broader biophysical operational principles were established, including a goal to protect at least 20% of each of 70 bioregions. Expert committees were established, including one to assess the representativeness of the existing and proposed reserve networks (Day et al. 2003; Fernandes et al. 2009), which helped to popularise the software Marxan (Ball & Possingham 2000). Two rounds of public consultation (in 2002 and 2003) resulted in over

30,000 submissions (GBRMPA 2003; Day 2017) and a Structural Adjustment Package (SAP) was established to compensate displaced fishers (Gunn et al. 2010; Macintosh et al. 2010).

In this article I will address both the RAP and the SAP, referring to them jointly as the 'GBR rezoning'.

Novel approach

Existing literature on the outcomes of systematic conservation plans typically represents the views of planners and scientists only (Giakoumi et al. 2018; McIntosh et al. 2018). This is also true for articles about the case studies in this paper (Pressey et al. 2002; Day et al. 2003; Fernandes et al. 2005). In this study I have attempted to engage a wider range of stakeholders involved with, and affected by, the plans. My interviewees often mentioned that they felt existing narratives around these plans were incomplete, and they were keen to ensure that a broader understanding of events was reported.

Material and methods

Selection of interviewees

Key informant interviewees were purposefully selected to represent views from across the sectors involved in high level negotiations around the planning case studies. They were categorised as: public servants, politicians, environmental and industry representatives and scientific advisors (Table 5.1).

Table 5.1: Breakdown of interviewees by case study and sector.

Sectors represented in key informant interviews	NE NSW forestry agreements [1995-2000]	Great Barrier Reef rezoning [1999-2004]
Public service (e.g. forestry, national parks, planning departments)	N09; N16; N28; N36; N48; N88	G07; G13; G31; G33; G45; G55; G69
Politics (e.g. environment minister)	N08	G19; G79; G99
Environmental representative (e.g. NGO)	N22; N46; N58; N62	G27
Industry (e.g. forestry, workers union, fisheries, tourism)	N44; N56; N84; N98	G01; G43; G77; G82
Scientific advisory (e.g. academic)	N32; N52; N76	G23; G63; G71; G89
TOTAL	18	19

These were broken into two types. The first type of interviewees were referred to as 'participant interviewees', those with direct involvement in negotiations around the design and approval of the plans (n=22). These interviewees were representative of all the major organisations involved in plan design and negotiations at a senior level in each case study (i.e. at least one interviewee from each government department, lobby group or other relevant organisation involved in the negotiations). They do not include all people involved in either planning instance, who number in the hundreds, but rather the most senior negotiators and decision-makers from each organisation or sector.

The second type of interviewees were referred to as 'contextual interviewees', who were closely associated with the case studies at a senior level but not involved directly in the negotiations at the time e.g. took on a senior management role immediately after the plans were completed (n=15). Contextual interviewees included evaluators and staff currently in senior management roles within relevant organisations.

Potential interviewees were initially identified based on documentation, then via snowball sampling. They were approached by email or phone with an invitation to participate, combined with further information. Response rates to email and phone requests to interview were high (90%), with only four non-replies and no refusals.

Interview method

Interviews were conducted in person in Brisbane, Sydney and Canberra or by phone during July and August 2016 and lasted from one to four hours. Interviews involved semi-structured questioning and interviewees were asked to reflect on their role during the planning process, how planning unfolded, about any monitoring or evaluations, and whether they thought the planning process had been effective (for example questions, see Appendix 5.1).

Analysis and interpretation

Subject to interviewee consent, interviews were digitally recorded and transcribed, and organised using the qualitative data analysis software NVivo (QSR International Pty Ltd. Version 11, 2015). Selective coding was used to identify data associated with the areas of interest for this study: barriers to evaluation, inhibiting factors or enabling conditions associated with evaluations, and perceptions of effectiveness. Within each dataset, open coding (Corbin & Strauss 2015) was used to identify concepts from the data. These were then grouped according to relatedness, resulting in a smaller set of overarching categories for each dataset. Where possible, claims made by interviewees were cross validated by responses from other

interviewees and documentary evidence was used to confirm key claims, where indicated in the results.

Results

Barriers to evaluation

In general, interviewees were able to identify more follow-up studies that had been conducted in relation to the GBR rezoning than to the forestry agreements in NE NSW (e.g. ecological monitoring or reports about the planning process). Examples included ecological monitoring (GBRMPA 2014a), social and economic monitoring (Marshall et al. 2017), and periodic assessments of states and trends of water quality and the condition of key ecosystems in the GBR (GBRMPA 2014b).

Open coding and categorisation of interview responses regarding barriers to evaluation led to the identification of three primary barriers: inadequate monitoring data, limited resources, and inadequate preparation.

Inadequate monitoring data

The inadequacy or absence of data with which to conduct policy evaluations was the first barrier identified. A shortage of suitable baseline data was often reported. One former GBRMPA employee [G07] stated, in hindsight, they would have implemented an ecosystem monitoring program prior to the rezoning, to enable tracing of the impacts before and after. This sentiment was echoed by a fishing lobbyist who stated this failure to establish baseline monitoring was "the worst thing they [GBRMPA] did" [G43].

Additionally, a lack of monitoring following plan implementation was often mentioned. Interviewees were generally unable to direct me to specific monitoring results for either environmental impacts or social impacts of the NE NSW forestry agreements. Legislative

requirements have meant that some monitoring has occurred in forestry compartments (e.g. pre-logging surveys) but to a lesser degree within the protected areas managed by the National Parks and Wildlife Service [N56]. A view shared by environmental and forestry representatives as well as former public servants, was the lack of a concerted effort or interest by the relevant government agencies to conduct the necessary monitoring. An assumption that protection automatically equates to improved condition was widespread at the time and continues today despite ongoing problems with invasive species and other threats in national parks [N76, N56]. One scientist argued that 'net conservation impact' should be based on whether the condition of habitats and species across both protected and unprotected areas increased or decreased relative to what would have otherwise occurred [N52].

Poor data management [N09] and a lack of compliance confounded attempts to establish impacts. In NSW compliance issues related to a lack of political will for enforcement of forestry prescriptions, and the complication of 'one arm of government taking another arm of government to court', resulting in a situation where, "our regulator is missing-in-action." [N22]. In the GBR, poor compliance primarily related to illegal fishing making it difficult to accurately compare the effects of no-take zones [G55, G63] (Williamson et al. 2014). External factors such as climate change and crown of thorn outbreaks further complicated attempts to attribute the impacts of the rezoning (De'ath et al. 2012).

Limited resources

A lack of resources, including time, money and motivation to undertake monitoring or evaluation exercises was also frequently raised. Underresourcing of relevant agencies was reported in NSW [N62] and in the GBR [G07]. In NSW this was partly due to the National Parks and Wildlife Service having been 'gutted' following the RFAs, leaving no money for survey work, species monitoring or management such as removal of invasive species, despite ongoing issues [N22].

In both contexts, staff exhaustion and limited capacity to adequately plan for monitoring was cited as part of the reason monitoring activities were not undertaken. Staff did not have the energy to consider what happened 'post-plan' [G13]. One interviewee put it very simply, "…everyone was fucked" [G69]. The personal cost of investing heavily in the lead up to the plan being accepted meant that once it was completed, staff were ready to return to their families and to step back from the intensity of the previous months.

Inadequate preparation

The third main barrier identified was inadequate preparation for future monitoring or evaluation. Scientists and planners commented that there had been no 'succession plan' or preparation for monitoring after the plans were developed, as the exercise was seen as a one-off activity. Evaluation and reporting were not a priority at the time, "…it was just straight on to the next big challenge…" [N52]. In addition, it was not clear whose responsibility it would be to undertake monitoring [G07].

Senior management at GBRMPA had planned to author an account of the rezoning process, to ensure it was accessible to audiences outside of the scientific literature. Funds had been allocated for this and technical write ups did occur (e.g. GBRMPA 2003), but not to the extent initially intended [G07, G89]. Had this been a higher priority at an earlier stage of planning, it would have been more likely to occur.

Inhibiting factors and enabling conditions

Barriers to evaluation do not arise in isolation. I also asked interviewees to discuss the inhibiting factors which prevented evaluation and the enabling conditions which facilitated evaluation in other circumstances. Inhibitory factors included: the need for political expediency and a loss of momentum post-plan. Enabling conditions included: value tied to monitoring and the capacity to undertake it, as well as the presence of strong leadership.

Political expediency

The need to seize a window of political opportunity demanded that planning personnel focus on immediate tasks to get plans approved, rather than on laying the foundations for implementation and future monitoring and evaluation. For example, after receiving 21,000 submissions in the second public consultation phase around the GBR RAP, a revised version of the plan had to be presented to parliament in less than four months. This involved a Herculean effort from GBRMPA staff to process an unprecedented number of submissions and revisions, yet the timing was absolutely key, "the reality is if we missed that window, the whole planned could've been thrown out ahead of the elections coming up" [G13].

However, establishing protected areas can be seen as 'one-off' investments, making going back to Cabinet to ask for more money for management very difficult [N08]. Five-yearly reviews of the RFAs were required, but they were not conducted as frequently as intended (twice between 1999 and 2016 (Spencer 2009; Waller 2018)) and were considered box ticking exercises [N22]. Accusations that the state government had no interest in transparency were common amongst environmentalists [e.g. N62] and scientists [e.g. N76] but also former senior staff in forestry [e.g. N16].

Loss of momentum

Another less obvious inhibiting factor was a loss of momentum to prepare for evaluation after the planning processes were concluded. A practical challenge included that staff moved on, prohibiting follow through. In NSW many of the staff working in the National Parks and Wildlife Service 'drifted off' [N09] and the corporate knowledge and centralised records were lost [N88]. GBRMPA had not been given additional resources to undertake the rezoning and had relied on internal restructuring of resources and staff time. This meant that after the rezoning, staff resumed their primary roles.

Political attention also moved on quickly after plans were completed. There was a federal election months after the GBR RAP took effect in 2004, and the attention of key players in GBRMPA was directed towards a review of the GBRMP Act (Commonwealth of Australia 2006), which led to changes in the authority's independence (Morrison 2017). In NSW the forestry agreements were finalised shortly before the Sydney Olympics commenced in 2000 and "all the money for doing anything around this just disappeared..." [N09]. An environmental NGO representative explained it in terms of a finite amount of political capital, which can only be directed towards crises and dissipates once a crisis has been averted [N58].

Value tied to monitoring

The principal enabling condition associated with successful monitoring and evaluation efforts was value tied to monitoring. For example, a desire to improve for future processes was cited as a motivation for a review of the Structural Adjustment Package (SAP) in the GBR [G63]. Many interviewees with a scientific background saw the value of monitoring, and senior managers in GBRMPA emphasised that the declaration of a conservation plan is not the end, "but really also the start of a whole new process of management" [G07]. Where monitoring was considered a lower priority by those responsible for allocating budgets in the relevant agencies, it appeared to be less common. The perception that the five-yearly reviews of the NE NSW RFA was not taken seriously further emphasised this impression [N16, N46].

Capacity for research and monitoring

The second enabling condition was capacity of the management agency and related organisations to undertake ecological or social research and monitoring which could subsequently support evaluations. Research agencies associated with the reef, such as the Australian Institute of Marine Science and research groups at James Cook University and elsewhere have meant significant research and monitoring capacity in the region. Many

interviewees [e.g. G63, G89] readily pointed to examples of ecological studies on the effects of marine reserves within the Great Barrier Reef (Russ et al. 2008; e.g. McCook et al. 2010).

Such capacity has been largely absent in relation to the NE NSW forestry agreements. One interviewee [N56] commented that the capacity of the National Parks and Wildlife Service to adequately manage the expanded estate was not discussed at the time. Even prior to the signing of the RFA, an independent expert working group had concluded that mechanisms for the effective management of the proposed reserved and forestry areas were not well developed (State of New South Wales & Commonwealth of Australia 1998).

Leadership

The presence or absence of strong leadership was key as to whether monitoring and reporting took place. Interestingly, in each case study a single individual emerged as the primary leader or champion, whose efforts, passion and skill influenced the planning process more than anyone else. A lack of leadership and responsibility with regards to monitoring and evaluation was reported amongst Ministers and the NSW National Parks and Wildlife Service. Despite many submissions and requests for action, leaders were seen to "nod their heads and go 'Mmm' and nothing happens" [N22]. Unlike in the Great Barrier Reef, I got the impression there was little desire amongst government agencies to seek information on policy outcomes and to improve in future, even where it was their primary responsibility.

Perceptions of effectiveness

To ascertain interviewees' opinions about the planning processes, they were asked 'was the planning process effective?'. The majority of respondents replied that the scientific and consultative aspects of both planning processes were largely effective, but that the handling of associated industry restructuring, and compensation was not. Open coding of responses identified four key themes in interviewees' perceptions of effectiveness, relating to: 1) whether

the planning process followed best available evidence and procedures, 2) the fact a planning result was agreed upon and implemented, 3) the longer-term influence of the plan, and 4) the consequences of industry restructuring. Note, respondents often used the terms 'effective' and 'success' interchangeably.

NE NSW forestry agreements

One respondent commented that both 'extremes' (referring to the conservation and forestry lobbyists) would report the forestry agreements as a failure because neither got everything they wanted. However, responses from interviewees were nuanced, with shared interpretations of the earlier interim forest agreements as having been more effective than the later RFA negotiations, where federal and state politics dominated [N16].

A key factor associated with perceptions of effectiveness was efforts to follow best available evidence and procedures, presumably on the assumption that good quality information and consultation processes lead to better outcomes. Referring to the interim forest agreements, a policy maker reported that they had never experienced a process before where data and the 'best ideas and tools' were so central [N28]. Clear 'rules of engagement' during the negotiations were valued by interviewees from all sectors. By the time the formal negotiations started, everyone had signed off on what data and tools (e.g. C-Plan and the Forest Resource and Management Evaluation System (FRAMES) (Forestry Corporation of NSW 2016)) would be used so discussions focused on how to act based on the available information [N09].

The intersection of rigorous science and strategic politics was also associated with good practice. One politically affiliated interviewee emphasised how politically resource intensive such policy debates are, and that they only work if you have a necessary level of commitment [N08]. However, environmental and forestry lobbyists alike felt that corruption of the political process towards the finalisation of the RFA rendered the investment of millions of dollars improving the underlying data meaningless [N46].

The fact a planning result was agreed upon and implemented was also a benchmark used to report effectiveness [N84, N44]. One interviewee stated that their measure for success was the fact people were chaining themselves to trees before the forestry agreements but were not afterwards [N36]. Those closest to Premier Carr's election commitment to expand national parks reported his leadership to have been key, whilst another less satisfied with the RFA outcome reported that Carr and others lacked the political resolve to see it through adequately at the final stages [N28].

The longer-term influence of the plan was the most frequently cited dimension of the perceived effectiveness of the forestry agreements. For some, the fact the plans remained in place influenced their definitions of success, "we always said if the reserves lasted 10 years we'd be happy" [N28]. However, interviewees were often not able to report whether the net outcome for biodiversity had been positive because of a lack of monitoring, limited management of threats in the national parks and concerns over compliance breaches with forestry operations. One interviewee noted that only a third of the area added to the reserve network would have been suitable for logging anyway (i.e. two thirds had not been at risk) [N09].

The consequences of industry restructuring raised most comments about ineffectiveness. For example: "If they hadn't caved to the industry at the end, (they were so close!)... it could have been a really historic agreement otherwise" [N28]. Interviewees from all sectors mentioned that native forestry timber yields from State Forests had been overestimated during the planning process, locking State Forests into contracts they could not meet (and later had to pay out (Goodwin 2014), 'selling the forest twice' [N56]). This was perceived as having led to significant mismanagement and over extraction from remaining forestry compartments in later years, which has made the industry unsustainable [N46] and represents a "callous disregard for the core principles of forestry" [N76]. Some went so far as to suggest there should be an admission that the RFA process failed and destroyed the future of the forest industry [N84].

Great Barrier Reef rezoning

Similar themes emerged in terms of perceptions of the effectiveness of the GBR rezoning. Most interviewees viewed the planning and execution of the RAP as a source of great pride. The view was shared by politicians [G19, G79] commercial fishing and tourism representatives [G01] as well as current executive staff and senior marine scientists [G33, G63]. The intersection of high quality scientific advice with political leadership was key, for example,

> "If you had the political without the scientific underpinning it, it would have been shit, and if you had a scientific underpinning without political process it would have never gotten anywhere, so it would have meant nothing. So, they are both equally important." [G69]

Strong leadership was particularly attributed to the then CEO of GBRMPA, the late Virginia Chadwick. Her political skills (as a former state government minister) were regularly cited as having shaped the course of the planning process because "she set the tone for actually talking with these people, not at them" and "everybody suddenly start[ed] to walk in tune" [G01]. This element of effectiveness is rarely reported in scientific documentation, but as another interviewee observed "…there's a whole lot of stuff behind the scenes, where you're basically advocating politically with key decision makers…" [G07].

GBRMPA's work to ensure widespread engagement across stakeholder groups and the broader Australian public also contributed to perceptions relating to the rigour and quality of the planning process. The Australian public is deeply invested in the GBR and "everybody has an opinion about it" [G01] so "at the end of the day it's the people who decide" [G07].

The fact the RAP was ultimately signed off by the Australian parliament and implemented was also commonly linked with perceptions of effectiveness and perceived as a relevant outcome for

reporting purposes. One politician made it clear that this was their primary performance measure:

> "Yes. It is effective because it got the outcome [parliamentary approval]."
>
> Interviewer asked, "Is that the sole determinant?"
>
> "What other determinate is there of effectiveness?" [G79]

As with the forestry agreements, the longer-term influence of the GBR rezoning was commonly cited in relation to perceptions of effectiveness. Interviewees often reported that the reef's health and resilience has improved, or at least been maintained relative to inaction, "Had we not done this, we would be in a far worse place. There's no doubt about that." [G01].

However, the longer-term influence of the SAP for displaced fishers was perceived by some as having "killed the future agenda" because the Environment Minister "opened the chequebook" [G31]. Many interviewees expressed strong opinions that the effectiveness of the RAP should be considered as separate from the SAP. However, frustration with the latter was regularly raised [e.g. G63, G71, G79, G89]. Approximately AUD $250 million was spent, twenty times that initially predicted and budgeted for, in part due to a looming election and the influence of marginal electorates along the GBR (Macintosh et al. 2010). This money was also seen as having had little impact on the overall amount of fishing in the GBR, given that small boat registrations continued unabated [G89] and commercial fishermen often shifted their fishing grounds elsewhere [G63].

Those who saw the RAP itself as ineffective largely did so because of a sense of inequality about who bore the burden of the decisions. Many are still angry at the way the commercial fishing industry was treated, with livelihoods lost and fishers ultimately excluded from many parts of the GBR [G99]. Recreational fishers were believed to have been listened to more than

commercial fishers when they requested their preferred fishing grounds be excluded from the new no-take zones [G77].

Discussion

Senior decision makers involved in the NE NSW forestry agreements and the GBR rezoning displayed a strong investment in the outcomes of the plans they painstakingly developed. However, for many, this was the first time they had been formally asked to speak about the effectiveness of the planning processes. Whilst they were generally very willing to recount their personal contributions, it was not uncommon for an interview to commence with a reminder that the version of events reported in the existing literature bore little resemblance to their experiences. This underscores the value of case study research and in-depth interviews, particularly in capturing a range of interpretations and perspectives around conservation planning exercises (Giakoumi et al. 2018).

Barriers to evaluation can be overcome

The primary barriers to evaluation identified in these case studies: a lack of suitable monitoring data, resource limitations and inadequate preparation, broadly matched those logistical considerations found in an earlier study involving conservation policy experts (Curzon & Kontoleon 2016) (Figure 5.1). However, none of my interviewees referred to the lack of a suitable control group as a barrier. This was perhaps because of a reduced emphasis on methodology in my questions and in the evaluation expertise of selected interviewees. These barriers confirm that the principal issues are not simply a lack of knowledge or inclination to conduct evaluations amongst conservation professionals.

The barriers reported here are also not unique to conservation and reflect those common in healthcare (Bach-Mortensen & Montgomery 2018), community energy projects (Hobson et al. 2016), natural resource management (Bellamy et al. 1999) and academia (Wilkinson 2017).

However, a key difference in my respondents' comments was that they rarely mentioned the difficulty of designing impact evaluations as a reason not to have attempted them. This may be because I interviewed senior decision makers who would have been contracting out evaluations to others, as in the case of the review of the SAP (Gunn et al. 2010).

The real value of these comparisons lies in improving our understanding of the inhibitory factors preventing evaluation, such as the need for political expediency and a loss of momentum post-plan, as well as the enabling conditions for evaluation, namely the value tied to monitoring, relative capacity to undertake research, and securing the necessary leadership. Similar factors have been reported in other policy sectors in Australia e.g. healthcare (Huckel Schneider et al. 2016), but also in vastly different governance contexts such as conservation programs in Samoa (Bottrill et al. 2011).

A key difference in the facilitating factors associated with conservation planning rather than other disciplines, is the significance of loss of momentum post-plan and drifting of political priorities. In sectors with more structured and centralised monitoring and reporting standards e.g. healthcare (Craig et al. 2008; Moore et al. 2015), this may be less likely to influence commitments to evaluation. As the conservation policy sector matures, it is hoped that will become less of a risk, and independent standards of best practice are increasingly being adopted across the sector (e.g. Conservation Measures Partnership 2013; Marine Conservation Institute 2018).

The fact that monitoring exercises were reported as having taken place in the GBR more often than in NE NSW may be due to greater public and international pressure, a stronger mandate within GBRMPA (than in NSW government departments) and the involvement of diverse reef user groups (e.g. tourism representatives were not mentioned amongst influential stakeholders in NE NSW) (Marshall et al. 2018). Differences in staffing, budgets and overall capacity may also be relevant, and have been shown to be the strongest predictors of conservation impact

(Gill et al. 2017). Without sufficient access to suitable data to undertake evaluations, and without careful design and preparation to ensure reporting of program outcomes, basic evaluations are unlikely, let alone high-quality evaluations involving counterfactual analyses.

Perceptions of effectiveness vary by stakeholder group

In both the NE NSW forestry agreements and GBR rezoning, most interviewees responded that the planning process and use of systematic conservation planning tools had largely been effective, but that the management of industry compensation had not been. Some chose to treat the two as distinct when it came to evaluating results and assessing contributions to later planning processes, however, others saw them as inseparable (more often those who were not responsible for the scientific aspects of planning, or who were impacted by the mishandling of compensation).

Perceptions of success and failure of conservation planning have been predominantly linked to contextual factors such as governance and socio-economic characteristics (e.g. degree of stakeholder support and overall cost of implementation), rather than elements of protected area design (Giakoumi et al. 2018). In the case of the GBR RAP, the responses I received broadly matched the two primary views reported in the Review of the Great Barrier Reef Marine Park Act (particularly findings 20 and 21) (Commonwealth of Australia 2006 p. 166), that the RAP was a) a "significant conservation achievement" according to stakeholders associated with tourism, science, conservation, shipping and some community groups, or b) a dissatisfying process, in which "the Authority [GBRMPA] was biased against them", a view reported by stakeholders from recreational and commercial fishing and associated industries.

It is no surprise that there is a link between the nature of experienced outcomes and stakeholder perceptions of effectiveness (Gurney et al. 2015; McNeill et al. 2018). Surveys have confirmed the low levels of trust commercial fishers continue to have for GBRMPA (Mackeracher et al. 2018), and the importance of values in shaping recreational fishers'

attitudes to the rezoning (Sutton & Tobin 2009). Closely connected is the finding that stakeholder engagement is amongst the most important factors associated with marine protected area success (Giakoumi et al. 2018). This view was shared by my interviewees, and stakeholder engagement was closely associated with perceptions about the quality and trustworthiness of the planning processes.

Seizing windows of political opportunity to enact the conservation plans was highly significant in the GBR and NSW, as in other conservation planning case studies (Pressey et al. 2013; Radeloff et al. 2013). Implementation was often reported by my interviewees alongside claims of effectiveness, however, the fact a plan was agreed on does not guarantee conservation impact. As was demonstrated in the case of NSW national parks, assumptions that protection equates to improved conditions for species and ecosystems, can be dangerous (Kapos et al. 2009; Pressey et al. 2015).

An alternative approach would be to define success in relation to initial program objectives, but this was uncommon amongst my interviewees, who were often thinking much more broadly about the consequences of the policies. While valuable for some stakeholders, limiting interpretations of effectiveness to such technical definitions or perspectives would be unsuitable for others (Axford et al. 2008). It may be that even where the impact of a conservation intervention is difficult to demonstrate, there is a motivation to report impact based on actions taken. This could be subconscious, or as suggested by one scientist [G89], a deliberate decision by lobby groups or organisations who feel the need to report success to their members or funders regardless of the quality of the plan (Pressey et al. 2017).

Facilitating future evaluations

The value of learning from the orchestrators of major policies cannot be understated (Selwyn 2013) and a shift in incentives to promote the sharing of information about how plans are developed and implemented is much needed. Efforts to rectify this information gap are

encouraging (e.g. Day 2016, 2017) as some of my interviewees felt the lessons from these planning processes have been underutilised. However, greater support needs to be provided by the organisations responsible for developing plans. Academic partnerships can also help to ensure write ups of how plans are conducted, closer to the point of implementation (e.g. Jumin et al. 2018). Systems for reporting among donors and proponents also help to shape the likelihood and nature of evaluations (Bottrill et al. 2011; Wilkinson 2017).

Given the range of audiences and interested parties involved in spatial planning, these stories should not be restricted to academic audiences either. This means extending funding and personnel contracts after the conclusion of a project and encouraging presentations of findings to a range of stakeholder groups, not just other scientists. As one interviewee emphasised, most people will never read academic publications.

To promote the conduct of rigorous impact evaluations, it may also help to compartmentalise evaluations to focus on particular aspects of a planning process, for example assessing why the SAP compensation dramatically exceeded expectations (Gunn et al. 2010). Promoting a relationship between evaluators and conservation scientists (much like that between medical researchers & clinicians) and reducing incentives to exaggerate claims of effectiveness could also help to improve the evaluation of conservation plans (Baylis et al. 2016). When it comes to reporting impact in relation to academic exercises, a large majority of respondents in a recent study suggested that a focus on impact needs to be embedded early on in a project (Wilkinson 2017). Other supportive factors included an understanding that research impact was on the organisation's agenda, and an improved understanding of what research impact means (Wilkinson 2017).

Based on lessons from other disciplines and related studies, when promoting future evaluations, government departments will want to consider the implications of high staff turnover, cumbersome approval processes, existing evaluation standards, as well as the role of

leadership and 'champions' (Bottrill et al. 2011; Huckel Schneider et al. 2016). Conservation champions played a prominent role in both case studies, where one person was consistently mentioned more than any other, based on their personal qualities, not necessarily seniority (Giakoumi et al. 2018).

Sharing lessons learnt

Documenting case studies like these helps to expose the range of perspectives on the success or failure of conservation planning initiatives and how to overcome barriers to the reporting of these outcomes. However, these case studies are not just history, they directly influence conservation policy today. The 'forest wars' over management of the native timber industry are back in Australia (Borschmann 2018), along with a decision to renew the RFAs indefinitely beyond their original twenty-year lifetime without having assessed their effectiveness (NSW Government 2018). Marine protection also remains highly contentious in Australia (Phillips 2017) and those who were involved with or affected by past planning decisions are often still highly influential.

A surprising observation was how frustrated interviewees were that important lessons had not been learnt. In a recent Senate debate on the future of the RFAs and the native forestry industry in Australia, Liberal senator Anne Ruston, Assistant Minister for Agriculture and Water Resources claimed we have 'learnt a lot in the last 20 years' yet accused "an industry of scientists who have made a fortune trying to come up with inconveniently ill-informed and unfactually based misinformation because it suits their purposes" (Commonwealth of Australia 2018, p 644). This devaluing of science appears to be on the rise in Australia (Lindenmayer 2017) and worldwide (Lubchenco 2017), threatening our ability to manage our resources effectively and efficiently.

When undertaking planning it is essential to remember the unique context of each plan (Adams et al. 2018) and it would be inappropriate to directly transpose the conclusions presented here

directly onto other contexts. The scale, level of conflict between resource users, degree of political capital invested, availability of planning expertise and quality of underlying biological data makes these plans unique. However, the majority of systematic conservation plans have been undertaken in similar, developed world contexts to date, in the USA, South Africa and Australia (Kukkala & Moilanen 2013; Álvarez-Romero et al. 2018; Sinclair et al. 2018), so general lessons are likely to be of value.

Conclusions

Spatial planning and natural resource management decisions are contentious for good reason. They shape the economic, social and environmental prospects of regions for decades or more, and inevitably involve value-laden decision-making, which results in winners and losers. For these and many other reasons, sharing lessons learnt is essential and can help to optimise future decision-making (Pendleton et al. 2018). Breaking down barriers to evaluation and knowledge sharing is an important first step.

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Overall discussion

"... the finding that much of the data in conservation does not reach the scientific literature supports the theory that the reliance on desk reviews of the scientific literature in order to assess approaches to evaluation in conservation is unlikely to be a fair or accurate assessment of what is happening in reality..."

(Curzon & Kontoleon 2016 p. 473).

As conservation scientists, our primary goal is to secure the world's biodiversity and remarkable ecosystems before it is too late. While there are many potential actions we can take, there is value in pausing and setting out carefully, after consideration of the potential effectiveness and efficiency of our actions. The values driving those of us with an interest in planning and evaluation relate to a belief in avoiding duplication of effort, learning from the attempts of others, and a conviction that, with more data and knowledge, near optimal solutions can be found (Editorial 2018). At the very least, prior preparation and clear objectives can make reflection easier later on (Guerrero et al. 2017).

In this chapter I will reiterate the aims of this thesis, synthesise my main findings, discuss the contribution of this thesis to the broader literature, share personal reflections and areas for improvement, and provide recommendations for future policy and research directions.

Summary of key findings

The goal of this thesis evolved from a relatively common origin amongst conservation practitioners – 'what works, and how can I apply it to future projects'. I gravitated towards systematic conservation planning (SCP) because of the potential for it to enable analyses of ecological information directly alongside the costings and social considerations so essential when it comes to implementation (Knight et al. 2011a; Kuempel et al. 2018). I had hoped to undertake a meta-analysis of correlates of success in existing systematic conservation plans and assess which aspects of successful plans are generalisable, irrespective of project and context. The identification of a significant evidence gap undermined this goal but highlighted opportunities to explore barriers to evaluation.

The central aim of this thesis was to explore the effectiveness of SCP exercises, including how effectiveness is perceived, measured and reported. This was broken into four secondary aims, progress against which is outlined below.

Aim 1: Formulate a conceptual approach to defining and measuring conservation impact in relation to SCP and determine what type of evidence is required to evaluate planning processes.

I explored conceptualisations of impact evaluation in the context of SCP in Paper 1. In doing so I characterised the discipline and outlined the type of information that would need to be collected to sufficiently evaluate 'wicked problems' in conservation, extending this to conservation planning interventions. This involved providing clarity on what would constitute outputs, outcomes and impacts, as well as how other planning disciplines have approached evaluation of similar process-based interventions. I compared theories of change designed for conservation planning interventions and developed a reporting framework to assist evaluators of plans (this was subsequently tested in Paper 4). This work has been published in *Annual Review of Environment and Resources* (McIntosh et al. 2017).

Aim 2: Characterise the extent and distribution of evidence on conservation outcomes of SCP around the globe.

The launching point for this thesis was an exploration of existing information on the implementation and outcomes of systematic conservation plans. This led to the development of a systematic map protocol (McIntosh et al. 2016; Paper 2), including definitions of SCP, outcomes, impacts and a theory of change suitable for my research question. After the peer-review and publication of the protocol, my co-authors and I screened over 10,000 articles. I recognised the inherent difficulty in comparing studies which reported to be about SCP. I also identified an imbalance in the literature towards studies focusing on methodological innovations, with very few studies reporting on implementation or the outcomes of plans. These findings were possibly as enlightening as the lessons learnt from the final three impact evaluations identified in the study. I concluded that the design of evaluations must be context-specific and that there is potential for greater reporting and use of quasi-experimental evaluation methods given adequate attention and resources. Both the protocol and final

systematic map (McIntosh et al. 2018; Paper 4) have been published in *Environmental Evidence.*

Aim 3: Assess tools and approaches for increasing the efficiency of evidence synthesis activities.

Systematic mapping and review exercises necessitate a team effort to manage large datasets, apply repeatable methods and keep careful records. As I found, this can be challenging, time consuming and expensive. The assessment I undertook of 22 software packages designed to provide end-to-end management of evidence synthesis projects highlighted innovations occurring outside the environmental sciences which have the potential to offer transparency and time saving. As interest in evidence synthesis methods grows in the environmental sciences (Sutherland et al. 2004; Pullin & Stewart 2006; Sutherland & Wordley 2018), increasing numbers of people stand to benefit from this overview of available software. I was invited to contribute this analysis to a publication introducing one of the software packages, CADIMA, and this work has been published in *Environmental Evidence* (Kohl et al. 2018).

Aim 4: Explore barriers to evaluation, through examination of landmark case studies in SCP.

To complement the breadth of the systematic map, I undertook an in-depth exploration of two influential SCP case studies. I spoke with senior decision makers in Australia involved in shaping the plans, regarding their interpretations of effectiveness and barriers to evaluation (Paper 5). My analysis of the interviewees' responses provided a rich understanding of the process of planning, interests involved and contexts in which evaluation is, or is not, encouraged and enabled. I demonstrated that perceptions of the effectiveness of plans are shaped by a) whether a high standard of planning is followed, b) the fact a planning result was agreed upon and implemented, c) the longer-term influence of the plan, and d) the consequences of industry restructuring. A particularly striking observation was the frequency with which interviewees remarked that the existing published literature on the plan in question

did not match their own understanding of events and outcomes. This work has been submitted to *Biological Conservation.*

Contributions of this thesis

This thesis demonstrates that claims of the effectiveness of SCP are not yet grounded on sufficient evidence. There are not enough examples of impact evaluations to enable general claims of effectiveness, or to transpose lessons from one context to another. The reasons for this are complex and reflect the fact that plans are multidimensional interventions, are often resourced only until completion and are rarely formally reflected upon. This situation is not unique to SCP and has been reported elsewhere, such as combined sustainability and human welfare interventions (e.g. Bowler et al. 2012), making the characterisation of barriers to evaluation and perceptions of effectiveness highly relevant to help minimise them in future.

In Paper 1 I suggested that the greatest opportunities for improved evaluation in conservation planning is aim for improved documentation and consideration of causality (Smith & Pell 2003; Curzon & Kontoleon 2016). Applications of SCP are likely to be highly context specific (Mills et al. 2015) therefore clear reporting of how plans were designed and implemented, using the reporting framework deployed in Paper 4, is strongly encouraged. They are also feasible, as the three included studies in Paper 4 demonstrate. Experimental, quasi-experimental and qualitative methods hold the greatest potential for impact evaluation studies in this discipline.

My understanding of SCP has evolved considerably since commencing this research. I initially believed it to be a discipline that was specifically intended for implementation, and to bridge the divide between academic idealism and on ground conservation actions. I no longer hold this simplistic view. As outlined in Paper 4, when it comes to defining a discrete intervention, the term SCP is too diverse. However, certain aspects may be more appropriate for direct

comparison e.g. the nature of stakeholder engagement. Perhaps a catch-all of 'systematic approaches to conservation planning' is most representative. Furthermore, the term SCP is also often misused by authors who are referring to spatial prioritisation exercises. I have added my voice to those of others before me who have pleaded for authors to distinguish more clearly between the two types of exercise (e.g. Knight et al. 2006a). They are incomparable, and confusion hinders evaluation and the sharing of lessons learnt.

I sought to contribute towards methodological developments to increase the efficiency of systematic maps and reviews. As a result of my discussions with others working in this area I was invited to join the Evidence Synthesis Technology Working Group (https://www.researchgate.net/project/Evidence-Synthesis-Technology-Methods-Group) and have produced publications on emerging research tools and opportunities to mainstream evidence synthesis exercises (Kohl et al. 2018; Westgate et al. 2018).

I also contributed a new perspective on well-known Australian examples of SCP by introducing the views of a wider range of stakeholders than have previously been featured in the academic literature (Paper 5). Semi-structured interviews are not a substitute for quasi-experimental impact evaluations but can offer valuable insights, so may prove useful in other situations where retrospective evaluation is difficult. This study also supported an emerging literature on barriers to evaluation (Bottrill et al. 2011; Curzon & Kontoleon 2016), confirming that logistical barriers and enabling conditions are important areas for consideration by organisations or project leads looking to promote evaluation. I outlined steps that can be taken to avoid barriers to evaluation in conservation, based on lessons from other disciplines.

A list of papers published, conferences I attended and presentations I delivered during this thesis is included in Appendix 6.1.

Reflections

There are several aspects of this thesis I would approach differently in future. In this study I employed the highest standard available for collating evidence in the published literature – systematic mapping. It represents an exhaustive search based on the sources I was able to get access to. I appreciate that evidence can take multiple forms (Bayliss et al. 2017), some of which will not have been captured using this approach, e.g. experiential evidence. My aim was to characterise the published evidence and gain a clearer picture of what was being published on this topic and what is not, an overview of which I have achieved. Furthermore, the conditions required to produce high quality evaluations are such that it is not likely that I have missed 'file drawer' evaluations, those which could be relevant but have not yet been published (Haddaway & Bayliss 2015).

The time and resources required to screen over 10,000 articles was excessive relative to the number of impact evaluations identified at the end of screening (n=3), however it was not possible to have known this prior to commencing the study. I now have a greater appreciation of the range of evidence synthesis methods. In a situation where few studies are likely to be available, alternative methods like rapid reviews may be more suitable in future (Collins et al. 2014; Cook et al. 2017; Haddaway & Dicks 2017; Greenhalgh et al. 2018). Groups like Conservation Evidence (www.conservationevidence.com) claim their approach is more cost-effective than systematic maps and reviews in fields with patchy datasets (Sutherland & Wordley 2018). I still believe there is great value in the rigour, transparency and repeatability of systematic maps and reviews (Westgate et al. 2018), but my experience has led me to appreciate that they are best suited where interventions are clearly defined, and evaluations are likely to have been standardised to a greater degree than in SCP.

The process of undertaking retrospective elite interviews was extremely enlightening and provided me with a stronger appreciation of the personal and political dimensions of planning from people I would not ordinarily have access to. Some discussions were especially valuable, for example,

> "You don't want the scientist who is managing the data gathering process to be worrying about the politics of it but equally, and this is a mistake I think a lot of scientists make, is that the politics is somehow the bad, that it is not appropriate that there be politics." [G79]

There were a small number of people I was not able to trace in the time available. In general, however, my interviewees were very keen to be involved and were generous in their responses. This was in part because I had been introduced to them via trusted contacts, was independent of the organisations involved and was offering the chance for them to share a very significant part of their careers.

Policy and future research recommendations

The 2020 deadline for the Convention of Biological Diversity Aichi Targets is looming (Maron et al. 2018) and even more ambitious targets are being discussed (e.g. 30% of the oceans (O'Leary et al. 2016)). If SCP is going to help secure priority areas for conservation, far greater attention needs to be paid to examples of implemented systematic conservation plans and their outcomes. A rush to create 'paper parks' or *ad hoc* reserves could undermine biodiversity conservation efforts in the longer term, hence best practice methods must be carefully interpreted and vigorously promoted (Knight et al. 2006a; Barnes et al. 2018).

I highlighted the necessity for a centralised repository of geo-located SCP projects and associated evaluation records, to track the continued expansion and influence of the discipline (Paper 1). I am currently contributing to a proposal for the UN Environment World Conservation Monitoring Centre to host a database of marine spatial plans (Álvarez-Romero et

al. 2018) which would include aspects of my systematic map database. This would be a valuable resource for governments looking to determine whether plans have been developed in their country, for conservation organisations looking to avoid duplicating existing efforts, and for researchers hoping to highlight knowledge gaps.

This thesis adds to prior calls highlighting insufficient academic attention awarded to applied SCP research (Knight et al. 2008). It is alarming to note that despite awareness of this knowledge gap, there has been no increase in the literature focusing on implementation and monitoring in recent years (Mair et al. 2018). This may be an example of academic novelty subsiding at a time when practitioners need guidance more than ever. Even when evaluations are conducted, it appears they are difficult to publish, based on the fact that the three included studies in Paper 4 were not published in the top journals in the discipline. I urge journal editors and academics to value the potential contribution of case study research (Knight et al. 2006a), and consider partnering with conservation organisations who may not otherwise have the resources to conduct evaluations themselves.

Enormous opportunities exist to enhance the use of technological approaches in evidence synthesis. In Westgate et al. (2018) we argued for better validation of new software tools so as to continue narrowing the 'synthesis gap' whilst ensuring that robust evidence syntheses continue to be developed. A group similar to our working group has also emerged in the healthcare sector to improve the automation of systematic reviews (Beller et al. 2018). Shortly after my review of tools was published, the software Colandr (Cheng et al. 2018) was released, which incorporates machine learning at screening and data extraction stages and has features designed specifically to support reviews of conservation related interventions. This is an exciting area of development and testing and I look forward to the review of tools (Paper 3) needing to be expanded in only a few years!

Another piece of research which will follow directly from this thesis relates to the reported outcomes of the two Australian SCP case studies, data which was not included in Paper 5. Interviewees completed a questionnaire and discussed outcomes according to a capitals framework (natural, financial, social, human and institutional capital) developed by Bottrill and Pressey (2012) (Table 2.3). The outcomes most widely reported to have increased as a result of the planning processes include new knowledge of ecological or social values, efficiency of operations and coordination between agencies. I hope to explore the degree to which reported outcomes are perceived to have influenced the conduct of subsequent planning exercises. My suspicion is that recent reticence to undertake ambitious SCP exercises in Australia (e.g. Barr & Possingham 2013) reflect concerns about the potential financial and political consequences if industry restructuring were to be mishandled again.

In this upcoming work I will also explore interviewees' perspectives on the relative roles of decision support tools (e.g. Marxan and C-Plan) in shaping the form and priorities outlined in the final version of the plan. My interviewees used Likert scales to report on the perceived level of influence of the decision support tools on resultant outcomes, as well as that of the broader procedural aspects of the planning process (e.g. consultation phases) and contextual factors, such as timing of elections. These results suggest stakeholders from all sectors (including conservation planners) considered the decision support tools to have played a significant role, but no more than procedural or contextual factors. In the case of the GBR rezoning, decision support tools reportedly had less influence on outcomes than procedural and contextual considerations. It seems SCP was not engaged with to its greatest extent (for example, it was not used to provide transparency when trade-offs were made between the costs of lost fishing licences and conservation gains), for understandable political reasons. These findings can be used to help manage expectations around the degree of influence SCP tools can hope to have on

multi-dimensional planning exercises relative to other procedural and contextual considerations.

Finally, exciting developments in the conservation evaluation community, like novel evaluation frameworks and practical approaches, are helping to make progress ever easier (Barnes et al. 2017; Fox et al. 2017; Mascia et al. 2017). The growth of the conservation evaluation community, united under the banner #teamcounterfactual also holds great potential for the enhancing awareness and adoption of evaluation methods. Literature on the evaluation of complex interventions in healthcare, including Medical Research Council guidelines (Craig et al. 2008; Moore et al. 2015; Tanner-Smith & Grant 2018), may help to standardise practice in conservation despite the differences between the disciplines. There are various areas of overlap, including challenges in defining interventions, difficulties in isolating 'active ingredients' in process-based interventions, and challenges for standardisation when accounting for context (Datta & Petticrew 2013; Hawe 2015).

Many opportunities exist to learn from disciplines other than healthcare as well, and bottom-up schemes hold significant potential for encouraging evidence-based practice in conservation. Examples include Project Oracle, where a practitioner guidebook is used to aid self-assessment of interventions directed at children and youth (Nutley et al. 2013), or Nesta's standards of evidence for impact investing (Puttick & Ludlow 2012). In these schemes, the entry level may only require that a theory of change has been developed and that there are plans for future evaluation, whereas the top level is reserved for interventions which have undergone numerous independent evaluations (Nutley et al. 2013). My own experience in attempting to incorporate evaluations into the workplan for an environmental monitoring and reporting program lead me to suggest this would be an extremely valuable starting point for practitioners (McIntosh et al. n.d.).

Concluding remarks

The identification of an absence of evidence of the outcomes of systematic conservation plans, suggestions for future evaluations and characterisation of barriers to evaluation, represent important steps towards improving conservation practice. Conservation is, after all, a battle against threats to species and ecosystems and as Eisenhower reportedly said, “in preparing for battle I have always found that plans are useless, but planning is indispensable.”

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Watson JEM, Dudley N, Segan DB, Hockings M. 2014. The performance and potential of protected areas. Nature 515:67–73.

Watson JEM, Grantham HS, Wilson KA, Possingham HP. 2011. Systematic conservation planning: Past, present and future. Pages 136–160 in R. J. Ladle and R. J. Whittaker, editors. Conservation Biogeography. Blackwell Publishing, Chichester, UK.

Watts ME, Ball IR, Stewart RS, Klein CJ, Wilson K, Steinback C, Lourival R, Kircher L, Possingham HP. 2009. Marxan with Zones: Software for optimal conservation based land- and sea-use zoning. Environmental Modelling & Software 24:1513–1521.

Watts ME, Possingham HP. 2016. Global users. Available from http://marxan.net/globe.

Watts MEJ. 2018. Global users. Available from http://marxan.net/index.php/globe (accessed April 3, 2018).

Weeks R et al. 2014. Developing marine protected area networks in the Coral Triangle: Good practices for expanding the Coral Triangle Marine Protected Area System. Coastal Management 42:183–205.

Wendt HK, Weeks R, Comley J, Aalbersberg W. 2016. Systematic conservation planning within a Fijian customary governance context. Pacific Conservation Biology 22:173–181.

Westgate MJ, Haddaway NR, Cheng SH, McIntosh EJ, Marshall C, Lindenmayer DB. 2018. Software support for environmental evidence synthesis. Nature Ecology & Evolution 2:588–590.

Westgate MJ, Likens GE, Lindenmayer DB. 2013. Adaptive management of biological

systems: A review. Biological Conservation **158**:128–139.

White H. 2009. Theory-based impact evaluation: Principles and practice. Page International Initiative for Impact Evaluation. Working Paper 3. International Initiative for Impact Evaluation (3ie), New Delhi.

Wiersma YF, Sleep DJH. 2016. A review of applications of the six-step method of systematic conservation planning. The Forestry Chronicle **92**:322–335.

Wilkinson C. 2017. Evidencing impact: a case study of UK academic perspectives on evidencing research impact. Studies in Higher Education:1–14.

Williams JC, ReVelle CS, Levin S a. 2005. Spatial attributes and reserve design models: A review. Environmental Modeling and Assessment **10**:163–181.

Williamson DH, Ceccarelli DM, Evans RD, Hill JK, Russ GR. 2014. Derelict fishing line provides a useful proxy for estimating levels of non-compliance with no-take marine reserves. PLoS ONE **9**:1–21.

Wilson KA et al. 2007. Conserving biodiversity efficiently: what to do, where, and when. PLoS Biology **5**:e223.

Wilson KA, Cabeza M, Klein CJ. 2009. Fundamental concepts of spatial conservation prioritization. Pages 16–27 in A. Moilanen, K. A. Wilson, and H. P. Possingham, editors. Spatial conservation prioritisation: Quantitative methods and computational tools. Oxford University Press, Oxford, UK.

WWF European Alpine Programme. 2005. Ecoregion conservation plan for the Alps. Prepared by WWF. Bellinzona, Switzerland.

Appendices

2.1 List of publications in test library

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-016-0069-4/MediaObjects/13750_2016_69_MOESM1_ESM.docx

2.2 Scoping of search terms and evolution of search string(s)

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-016-0069-4/MediaObjects/13750_2016_69_MOESM2_ESM.docx

2.3 Data extraction form/coding tool and typologies

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-016-0069-4/MediaObjects/13750_2016_69_MOESM3_ESM.xlsx

2.4 Proposed data presentation matrix

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-016-0069-4/MediaObjects/13750_2016_69_MOESM4_ESM.xlsx

3.1 Search strategy for identifying software programs

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-018-0115-5/MediaObjects/13750_2018_115_MOESM1_ESM.docx

3.2 CADIMA terms of service

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-018-0115-5/MediaObjects/13750_2018_115_MOESM2_ESM.docx

4.1 Detailed search methods and results (also available as an excel file online)

Source (Title, date searched, weblink)	Search string	Search details	Results
Web of Science, Core Collection 28/02/2017 https://apps.webofknowledge.com	TS=(aquatic OR "river basin" OR ecoregion* OR bioregion* OR terrestrial OR marine OR freshwater OR coastal OR landscape OR seascape OR catchment OR "coastal zone" OR "ecological network" OR corridor OR "conservation area" OR "reserve network" OR "protected area" OR "national park" OR "planning unit") AND TS=("conservation plan*" OR "spatial plan*" OR "conservation assessment" OR "reserve selection" OR "area selection" OR "reserve design*" OR "conservation zoning" OR "key biodiversity area" OR "important bird area" OR "spatial priorit*"OR "conservation priorit*" OR "conservation area priorit*" OR "spatial optimi*" OR "protected area network design" OR "resource allocation" OR "conservation decision making" OR marxan OR zonation OR "C-Plan" OR RobOff OR BioRap OR CLUZ OR ConsNet OR CPLEX OR CREDOS OR "Ecoseed Marzone" OR MinPatch OR MultCSync OR NatureServeVista OR ResNet OR SPEXAN OR "conservation evaluation" OR "area identification" OR "decision-support tool" OR "conservation action") AND TS=(outcome* OR evaluat* OR output* OR impact* OR effect* OR ineffective OR success* OR fail* OR benefit* OR implement*) AND TS=(biodivers* OR wildlife OR species OR habitat)	Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=1983-2017. Ordered by publication date, newest first	4790
Scopus 28/02/2017 www.scopus.com	(TITLE-ABS-KEY (aquatic OR "river basin" OR ecoregion* OR bioregion* OR terrestrial OR marine OR freshwater OR coastal OR landscape OR seascape OR catchment OR "coastal zone" OR "ecological network" OR corridor OR "conservation area" OR "reserve network" OR "protected area" OR "national park" OR "planning unit") AND PUBYEAR > 1982) AND (TITLE-ABS-KEY ("conservation plan*" OR "spatial plan*" OR "conservation assessment" OR "reserve selection" OR "area selection" OR "reserve design*" OR "conservation zoning" OR "key biodiversity area" OR "important bird area" OR "spatial priorit*" OR "conservation priorit*" OR "conservation area priorit*" OR "spatial optimi*" OR "protected area network design" OR "resource allocation" OR "conservation decision making" OR marxan OR zonation OR "C-Plan" OR roboff OR biorap OR cluz OR consnet OR cplex OR credos OR "Ecoseed Marzone" OR minpatch OR multcsync OR natureservevista OR resnet OR spexan OR "conservation evaluation" OR "area identification" OR "decision-support tool" OR "conservation action") AND PUBYEAR > 1982) AND (TITLE-ABS-KEY (outcome* OR evaluat* OR output* OR impact* OR effect* OR ineffective OR success* OR fail* OR benefit* OR implement*) AND PUBYEAR > 1982) AND (TITLE-ABS-KEY (biodivers* OR wildlife OR species OR habitat) AND PUBYEAR > 1982)	Date range > 1982	6545
CAB Abstracts (via Ovid®) 1972 to 2017 Week 07 28/02/2017 https://www.cabi.org/publishing-products/online-information-resources/cab-abstracts/		Advanced search (keywords, which is mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes]) on subject, intervention, outcome and qualifier search terms separately and then combined with AND. Limited from 1983 - 2017	1798

Google scholar 24/02/2017 https://scholar.google.co.uk/	allintitle: evaluation "conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Searched on title words only, must include 'evaluation'. 1983-2017	80
Google scholar 24/02/2017 https://scholar.google.co.uk/	allintitle: "conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Date range: 1983-2017. Top 999 most relevant out of 6970 articles (it was not possible to download the top 1000 for an unknown reason)	999
Open Grey 01/03/2017 http://www.opengrey.eu/	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Basic search on the GS search string. Not limited by date, nor restricted by title. Extracted using Parsehub and tidied in Excel prior to conversion to .ris	51
PAIS Index (PAIS International) 01/03/2017 http://www.proquest.com/products-services/pais-set-c.html	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Advance search on Google Scholar search string, for the date range 1983-2017. Did not restrict by title, because several potentially relevant records were returned on a search 'anywhere' in which the search terms were in the abstract but not the title. Only 34 results when I searched on title only.	116
ProceedingsFirst (OCLC) 01/03/2017 http://www.oclc.org	ti: conservation w plan OR ti: conservation w planning OR ti: spatial w plan OR ti: conservation w assessment OR ti: reserve w design OR ti: conservation w zoning and yr: 1983-2017	Advance search on Google Scholar search string, for the date range 1983-2017. Restricted by title. Not possible to search 'anywhere'. NB: The Title index contains words from the title and translated or variant forms of titles.	3
PapersFirst 01/03/2017 http://www.oclc.org	ti: conservation w plan OR ti: conservation w planning OR ti: spatial w plan OR ti: conservation w assessment OR ti: reserve w design OR ti: conservation w zoning and yr: 1983-2017	Advance search on Google Scholar search string, for the date range 1983-2017. Restricted by title. Not possible to search 'anywhere'. Processed using Endnote online to convert to a file format (RefMan ris format) which could be imported into EPPI Reviewer	175
Campbell Collaboration 09/02/2017 www.campbellcollaboration.org /lib/	inall: "conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Limited to 1983-2017. Also searched each search term individually, still no results.	0
Center for International Forestry Research (CIFOR) - Library 01/02/2017 www.cifor.org/library/	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Basic keywords (topics and abstracts) search, not restricted by date. Advanced search did not detect words when "" were used, whereas basic search did.	19
Environmental Evidence 09/02/2017 www.environmentalevidence.org	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Also searched each search term individually. Only 1 result, the protocol written by the authors of this study, so it was disregarded.	0
Conservation Evidence 09/02/2017 www.conservationevidence.com	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Also searched each search term individually.	0
Coral Triangle Initiative 09/02/2017 http://www.coraltriangleinitiative.org	"conservation plan" "conservation planning" "spatial plan" "conservation assessment" "reserve design" "conservation zoning"	Advanced search, using 'containing any of the words'. (Note, searches on individual terms confirmed the combined string was returning the expected results). Search returned three results, one was an academic paper, one an FAQ and another a news article about the first academic article. The FAQ and news article were discarded before results were downloaded.	1
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia 42776 https://publications.csiro.au/	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Basic search (author, title, abstract, keywords). Not limited by date but all records are since 1983.	127

Evidence on Demand 42776 http://www.evidenceondemand.info/library.aspx	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	General search, not limited by date. Also searched each search term individually.	0
IUCN Evaluations database 42776 https://www.iucn.org/monitoring-and-evaluation/monitoring-our-work/evaluations-database	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	There were 427 records in the evaluations database but not possible to search on document metadata. A search on titles (i.e. a search within the page) did not return any of the google scholar search terms.	0
IUCN Library System 42776 https://portals.iucn.org/library/dir/publications-list	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	All searches limited to 1983 and later. The combined search string returned no results however individual search terms did, for "conservation planning" only.	9
Natureserve 42800 http://www.natureserve.org/biodiversity-science/publications	NA	Publications database does not have a keyword search option, instead I sorted by the category 'Conservation and Land-use planning' which returned approx. 20 results over 2 pages. It was not possible to use web scraping so results were manually extracted.	20
Poverty and Conservation Learning Group - Bibliographic database 42782 https://www.povertyandconservation.info/en/bibliographies	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "conservation zoning"	Not enough room to include all terms in search string, but searching "reserve design" alone returned no results, so it was excluded. The combined string returned similar results to individual search terms. No other search limits. Partially manually downloaded because web scraping did not capture all metadata.	21
Poverty and Conservation Learning Group - Biodiversity-poverty evidence database 42782 https://www.povertyandconservation.info/biodiversity-poverty-evidence	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservati	Advanced search couldn't fit entire search string, so terms searched individually. Searches not constrained otherwise. 1 result for "spatial plan" and 2 results for "conservation zoning"	3
Poverty and Conservation Learning Group - PCLG publications 16/02/2017 https://www.povertyandconservation.info/en/pclg-publications	GS search string keywords	No search feature, so search within the page (which included title, authors and one line of each abstract) for my six keywords, with no results. A manual check confirmed no relevant titles.	0
Protected Planet 16/02/2017 www.protectedplanet.net		Publications and resources not relevant (hand searched)	0
SANBI Planning database, South Africa 16/02/2017 http://www.sanbi.org/information/documents	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" in <Any> category AND "conservation zoning" in <Any> category		0
The Digital Observatory for Protected Areas (Europe) 16/02/2017 http://dopa.jrc.ec.europa.eu/en/documentation	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Individual keyword search (within pages) across all document types. Restricted to post-2010 so also searched the Joint Research Centre.	0
United Nations Environment Programme – World Conservation Monitoring Centre 17/02/2017 https://www.unep-	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Full search string returns no results but individual search terms returned 63 results after removal of duplicates.	63

wcmc.org/resources-and-data			
Biodiversity Heritage Library 17/02/2017 http://www.biodiversitylibrary.org/search?searchTerm=WCMC#/titles	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	This database contains historic WCMC reports. Combined search string only returns results associated with the first term ("conservation plan"). However searching for terms individually returned 27 results (after removal of duplicates)	27
USAID Development Experience Clearinghouse (Evaluations) 03/04/2017 https://dec.usaid.gov/dec/content/evaluations.aspx	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning" limited by: Evaluation	Reached this search by directly going into the 'Evaluations' section from the USAID Development experience clearinghouse homepage, then chose 'All evaluations' under the 'Evaluations in the DEC' header. Filtered according to the GS search terms (under the 'DEC' tab rather than the 'DEC Google Search' tab). No other limitations. Manually extracted results and converted from .xls to .ris	3
USAID Biodiversity Conservation Gateway 03/04/2017 https://rmportal.net/biodiversityconservation-gateway	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Advanced search, by 'Search this website: Search the entire Biodiversity Conservation Gateway site'. Only 9 unique results (15 results returned but 6 were chapters from a single book).	9
World Wildlife Fund for Nature International 07/03/2017 wwf.panda.org	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	Returns 18 results over two pages. Manually downloaded and converted from .xls to .ris	18
		TOTAL RESULTS (prior to duplicate checking)	14877

Other searches

Of the proposed list of organisational websites in our original protocol, searches were attempted on the following but we were unable to extract records. Explanations and work arounds are explained below.

Source	Search string	Search details	Result
The Nature Conservancy – Conservation Gateway 13/02/2017 http://www.conservationgateway.org/Pages/Advanced-Search.aspx	"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"	No limiting fields so a wide range of results appear, including websites. Due to inconsistencies in formatting it was not possible to use web scraping successfully to retrieve the required metadata such as abstracts. Rather than arbitrarily downloading a subset of the studies, we did not include any and made sure to contact subject experts from The Nature Conservancy.	3344
OECD iLibrary 15/02/2017 http://www.oecd-ilibrary.org/	All Fields containing '"conservation plan" OR "conservation planning" OR "spatial plan" OR "conservation assessment" OR "reserve design" OR "conservation zoning"'	Advanced search on studies published between 1900 and 2017. Attempted to extract all records using web scraping with Parsehub, however this was unsuccessful due to an anti-bot feature. The OECD iLibrary staff were not able to assist so a decision was made to exclude this website from the search due to the inability to search and scrape it repeatably. Furthermore, a quick review of search results suggested the terms returned many irrelevant studies, and inconsistency in formatting of metadata meant web scraping would not have been effective even if the anti-bot feature was not in place.	2009
Wildlife Conservation Society 07/03/2017 www.wcs.org	NA	Website did not provide a centralised repository of potentially relevant publications. Instead subject experts from this organisation were contacted.	NA
Critical Ecosystem Partnership Fund	NA	Excluded based on the advice of a co-author with more experienced with the organisation, who suggested it likely to include relevant studies.	NA

Subject experts who responded and number of records they were able to recommend

Name	Organisation	Total number of records recommended	New records
Craig Groves	Retired, formerly The Nature Conservancy	0	0
Edward Game	The Nature Conservancy	2	1
Piero Visconti	University College London	0	0
Stephen Woodley	International Union for Conservation of Nature	0	0
Tom Brooks	International Union for Conservation of Nature	0	0
Stacy Jupiter	Wildlife Conservation Society	1	0
James Watson	Wildlife Conservation Society	0	0
Rodolphe Devillers	Memorial University of Newfoundland	0	0
Madeleine McKinnon	Vulcan Inc.	169	145
Robert Pressey	James Cook University	0	0
Matthew Smith	Joint Nature Conservation Committee, UK	0	0
Hugh Possingham	UQ, The Nature Conservancy	0	0
Robert Smith	DICE, University of Kent	0	0
Rebecca Shaw	WWF Chief Scientist	0	0
Richard Cowling	Nelson Mandela Metropolitan University	2	0
Rebecca Weeks	James Cook University	0	0
Frank Davis	UCSB	1	0
John Morrison	World Wildlife Fund	0	0
David Wilkie	Wildlife Conservation Society	2	2
Genevieve Pence	CapeNature	8	8
Jorge Alvarez-Romero	James Cook University	2	0
	TOTAL	187	156
	TOTAL INCLUDED IN ANALYSIS*	185	154

* Two unique reports were provided after analysis had been concluded

4.2 Coding template and included studies, coded

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-018-0134-2/MediaObjects/13750_2018_134_MOESM2_ESM.xlsx

4.3 Forward and backwards citation searches of included articles

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-018-0134-2/MediaObjects/13750_2018_134_MOESM3_ESM.xlsx

4.4 List of articles unavailable at full-text or unavailable in English

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-018-0134-2/MediaObjects/13750_2018_134_MOESM4_ESM.docx

4.5 List of articles excluded at full-text stage, including reasons for their exclusion

Available online: https://static-content.springer.com/esm/art%3A10.1186%2Fs13750-018-0134-2/MediaObjects/13750_2018_134_MOESM5_ESM.pdf

4.6 Review articles excluded at full-text screening (also available online)

The following articles were considered reviews of systematic conservation planning and evaluation of the discipline, rather than examples of relevant interventions.

1. Balmford A. Conservation planning in the real world: South Africa shows the way. Trends Ecol. Evol. 2003;18:435–8.
2. Cowling R., Pressey R. Introduction to systematic conservation planning in the Cape Floristic Region. Biol. Conserv. 2003;112:1–13.
3. Esfandeh S, Kaboli M, Eslami-Andargoli L. A Chronological review on application of MARXAN tool for systematic conservation planning in landscape. Int. J. Eng. Appl. Sci. 2015;2:6–17.
4. Knight AT, Driver A, Cowling RM, Maze K, Desmet PG, Lombard AT, et al. Designing systematic conservation assessments that promote effective implementation: Best practice from South Africa. Conserv. Biol. 2006;20:739–50.
5. Leslie H. A synthesis of marine conservation planning approaches. Conserv. Biol. Blackwell Science Inc; 2005;19:1701–13.
6. McIntosh EJ, Pressey RL, Lloyd S, Smith RJ, Grenyer R. The impact of systematic conservation planning. Annu. Rev. Environ. Resour. 2017;42:677–97.
7. Wiersma YF, Sleep DJH. A review of applications of the six-step method of systematic conservation planning. For. Chron. 2016;92:322–35.

Note: none of these are systematic reviews and they vary in their form and content. It is possible that other papers which could be loosely referred to as a review have been screened at full-text instead.

4.7 List of articles included on subject, intervention and outcome, but excluded on comparator and study design (also published online)

1. Arkema KK, Verutes GM, Wood S, Clarke-Samuels C, Rosado S, Canto M, et al. Embedding ecosystem services in coastal planning leads to better outcomes for people and nature. Proc. Natl. Acad. Sci. 2015;112:7390–5.
2. Barr LM, Possingham HP. Are outcomes matching policy commitments in Australian marine conservation planning? Mar. Policy. 2013;42:39–48.
3. Blau J, Green L. Assessing the impact of a new approach to ocean management: Evidence to date from five ocean plans. Mar. Policy. 2015;56:1–8.
4. Bottrill MC, Mills M, Pressey RL, Game ET, Groves C. Evaluating perceived benefits of ecoregional assessments. Conserv. Biol. 2012;26:851–61.
5. Brownlie S, De Villiers C, Driver A, Job N, Von Hase A, Maze K. Systematic conservation planning in the Cape Floristic Region and Succulent Karoo, South Africa:

Enabling sound spatial planning and improved environmental assessment. J. Environ. Assess. Policy Manag. 2005;7:201–28.
6. Cabral R, Mamauag S, Alino P. Designing a marine protected areas network in a data-limited situation. Mar. Policy. 2015;59:64–76.
7. Day J. The need and practice of monitoring, evaluating and adapting marine planning and management-lessons from the Great Barrier Reef. Mar. Policy. 2008;32:823–31.
8. Dobbs K, Fernandes L, Slegers S, Jago B, Thompson L, Hall J, et al. Incorporating marine turtle habitats into the marine protected area design for the Great Barrier Reef Marine Park, Queensland, Australia. Pac. Conserv. Biol. 2007;13:293–302.
9. Driver A. CEPF final project completion report. Pretoria, South Africa; 2006.
10. Fernandes L, Day J, Lewis A, Slegers S, Kerrigan B, Breen D, et al. Establishing representative no-take areas in the Great Barrier Reef: Large-scale implementation of theory on marine protected areas. Conserv. Biol. 2005;19:1733–1744.
11. Game ET, Lipsett-Moore G, Hamilton R, Peterson N, Kereseka J, Atu W, et al. Informed opportunism for conservation planning in the Solomon Islands. Conserv. Lett. 2011;4:38–46.
12. Green A, Smith SE, Lipsett-Moore G, Groves C, Peterson N, Sheppard S, et al. Designing a resilient network of marine protected areas for Kimbe Bay, Papua New Guinea. Oryx. 2009;43:488–98.
13. Hannah L, Panitz D, Midgley G. Cape floristic region, South Africa. In: Hilty JA, Chester CC, Cross MS, editors. Clim. Conserv. Landsc. Seascape Sci. Planning, Action. Washington, D.C.: Island Press-Center for Resource Economics; 2012.
14. von Hase A, Rouget M, Maze K, Helme N. A fine-scale conservation plan for Cape lowlands renosterveld: technical report. Claremont, South Africa; 2003.
15. von Hase A, Rouget M, Cowling RM. Evaluating private land conservation in the cape lowlands, South Africa. Conserv. Biol. 2010;24:1182–9.
16. Henson A, Williams D, Dupain J, Gichohi H, Muruthi P. The Heartland Conservation Process: enhancing biodiversity conservation and livelihoods through landscape-scale conservation planning in Africa. Oryx. 2009;43:508.
17. Laffoley D, White AT, Kilarski S, Gleason M, Smith S, Llewellyn G, et al. Establishing Resilient Marine Protected Area Networks — Making It Happen. Washington, D.C.: The World Conservation Union; 2008.
18. Klein CJ, Jupiter SD, Watts M, Possingham HP. Evaluating the influence of candidate terrestrial protected areas on coral reef condition in Fiji. Mar. Policy. Elsevier; 2014;44:360–5.
19. Knight AT, Cowling RM, Boshoff AF, Wilson SL, Pierce SM. Walking in STEP: Lessons for linking spatial prioritisations to implementation strategies. Biol. Conserv. 2011;144:202–11.
20. Lipsett-Moore G, Hamilton R, Peterson N, Game E, Atu W, Kereseka J, et al. Ridges to Reefs Conservation Plan for Choiseul Province, Solomon Islands. TNC Pacific Islands Countries Report No. 2/10. 2010.
21. Mangubhai S, Wilson JR, Rumetna L, Maturbongs Y, Purwanto. Explicitly incorporating socioeconomic criteria and data into marine protected area zoning. Ocean Coast. Manag. Elsevier Ltd; 2015;116:523–9.
22. Mendel LC, Kirkpatrick JB. Historical progress of biodiversity conservation in the protected-area system of Tasmania, Australia. Conserv. Biol. 2002;16:1520–9.
23. Morrison J, Loucks C, Long B, Wikramanayake E. Landscape-scale spatial planning at WWF: a variety of approaches. Oryx. 2009;43:499–507.
24. Nel JL, Roux DJ, Driver A, Hill L, Maherry AC, Snaddon K, et al. Knowledge co-production and boundary work to promote implementation of conservation plans. Conserv. Biol. 2016;30:176–88.

25. Northern Territory Government. Draft Conservation Plan for the Daly Basin Bioregion. Darwin, Northern Territory; 2003.
26. Nutters HM, Pinto da Silva P. Fishery stakeholder engagement and marine spatial planning: Lessons from the Rhode Island Ocean SAMP and the Massachusetts Ocean Management Plan. Ocean Coast. Manag. Elsevier Ltd; 2012;67:9–18.
27. Osmond M, Airame S, Caldwell M, Day J. Lessons for marine conservation planning: A comparison of three marine protected area planning processes. Ocean Coast. Manag. 2010;53:41–51.
28. Pence GQK. Western Cape Biodiversity Framework 2014 Status Update: Critical Biodiversity Areas of the Western Cape. Unpublished CapeNature project report. Cape Town, South Africa; 2014.
29. Pence GQK. C.A.P.E. fine-scale systematic conservation planning assessment: Technical report. Produced for CapeNature as part of the GEF-funded C.A.P.E. Fine-Scale Biodiversity Planning Project. Cape Town, South Africa; 2008.
30. Pierce SM, Cowling RM, Knight AT, Lombard AT, Rouget M, Wolf T. Systematic conservation planning products for land-use planning: Interpretation for implementation. Biol. Conserv. 2005;125:441–58.
31. Pressey R., Whish G., Barrett T., Watts M. Effectiveness of protected areas in north-eastern New South Wales: recent trends in six measures. Biol. Conserv. 2002;106:57–69.
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4.8 Retrospective tests of initial search string (also available as an excel file online)

Web of Science Core Collection 24/01/2018 https://apps.webofknowledge.com

Search string	Search details	Results
TS=(aquatic OR "river basin" OR ecoregion* OR bioregion* OR terrestrial OR marine OR freshwater OR coastal OR landscape OR seascape OR catchment OR "coastal zone" OR "ecological network" OR corridor OR "conservation area" OR "reserve network" OR "protected area" OR "national park" OR "planning unit")	Rerun of original 'subject' string, Fisher and Dills was NOT returned. NB searches were all limited from 1983-2017.	930331
TS=("conservation plan*" OR "spatial plan*" OR "conservation assessment" OR "reserve selection" OR "area selection" OR "reserve design*" OR "conservation zoning" OR "key biodiversity area" OR "important bird area" OR "spatial priorit*"OR "conservation priorit*" OR "conservation area priorit*" OR "spatial optimi*" OR "protected area network design" OR "resource allocation" OR "conservation decision making" OR marxan OR zonation OR "C-Plan" OR RobOff OR BioRap OR CLUZ OR ConsNet OR CPLEX OR CREDOS OR "Ecoseed Marzone" OR MinPatch OR MultCSync OR NatureServeVista OR ResNet OR SPEXAN OR "conservation evaluation" OR "area identification" OR "decision-support tool" OR "conservation action")	Rerun of original 'intervention' string, Fisher and Dills was returned	70252
TS=(outcome* OR evaluat* OR output* OR impact* OR effect* OR ineffective OR success* OR fail* OR benefit* OR implement*)	Rerun of original 'outcome' string, Fisher and Dills was returned	17495871
TS=(biodivers* OR wildlife OR species OR habitat)	Rerun of original 'qualifier' string, Fisher and Dills 2012 was returned	1832855
TS=(aquatic OR "river basin" OR ecoregion* OR bioregion* OR terrestrial OR marine OR freshwater OR coastal OR landscape OR seascape OR catchment OR "coastal zone" OR "ecological network" OR corridor OR "conservation area" OR "reserve network" OR "protected area" OR "national park" OR "planning unit") AND TS=("conservation plan*" OR "spatial plan*" OR "conservation assessment" OR "reserve selection" OR "area selection" OR "reserve design*" OR "conservation zoning" OR "key biodiversity area" OR "important bird area" OR "spatial priorit*"OR "conservation priorit*" OR "conservation area priorit*" OR "spatial optimi*" OR "protected area network design" OR "resource allocation" OR "conservation decision making" OR marxan OR zonation OR "C-Plan" OR RobOff OR BioRap OR CLUZ OR ConsNet OR CPLEX OR CREDOS OR "Ecoseed Marzone" OR MinPatch OR MultCSync OR NatureServeVista OR ResNet OR SPEXAN OR "conservation evaluation" OR "area identification" OR "decision-support tool" OR "conservation action") AND TS=(outcome* OR evaluat* OR output* OR impact* OR effect* OR ineffective OR success* OR fail* OR benefit* OR implement*) AND TS=(biodivers* OR wildlife OR species OR habitat)	Rerun of the entire original search string, Fisher and Dills 2012 was not returned (NB outcome and intervention strings combined resulted in 40387 results)	5353
TS=(aquatic OR "river basin" OR ecoregion* OR bioregion* OR terrestrial OR marine OR freshwater OR coastal OR landscape OR seascape OR catchment OR "coastal zone" OR "ecological network" OR corridor OR "conservation area" OR "reserve network" OR "protected area" OR "national park" OR "planning unit" OR protection)	Revised subject search string, including 'protection'	1390772
Revised subject search string combined with the above original intervention, outcome and qualifier search strings (combined using 'AND').		5695
Final notes		
Difference in the number of results returned from the revised search string on 24/01/2018 and the original Web of Science search on 28/02/2017 (4790 results)		905
Studies added in the intervening 11 months since the first search (based on the original search string)		563
Difference due to the inclusion of the subject term 'protection', excluding studies added in the intervening 11 months		342

5.1 Paper 5 supplementary materials

Semi-structured interviews: example questions

Interviewee background details

- Role(s) during the case study conservation planning process and timing/duration of each role
- Current associations with the case study or key individuals involved in the case study
- Involvement in any other conservation planning activities at any time

Reflections on the planning process

- How the planning process unfolded.
- Would there have been anything you would have done differently or would do differently in terms of the process followed?
- The tool (e.g. Marxan, C-Plan) was used during the planning process, what was your involvement with this aspect of the planning process?
- What personalities were involved in the development of the plan?
- What other local concerns were present at that time?
- Do you have an idea of the approximate cost of the planning process?
- Since the plan was completed, do you think it has had any impacts on other conservation plans? If so which, and why?

Outcomes

Interviewees were invited to discuss the outcomes they perceived to have arisen from the planning process according to a framework which breaks down natural, social, financial, human and institutional capital outcomes into a series of subcategories (Bottrill et al. 2012). The results of the questionnaire and associated interview discussions have not been included here and will be published separately.

Evaluations

- Would you describe the planning process as having been effective? Why/why not?
- How do you predict the outcomes may have been different in the absence of the plan?
- Are you aware of any evaluations having been conducted in relation to this planning process or its subsequent outcomes (informal or formal)?
- Why do you think monitoring/evaluations were not undertaken?

Closing remarks

- In light of our discussion, is there anything you would change or add to your responses?
- Do you have any recommendations for other people I should contact?

Case study selection

The promotion of science-informed natural resource planning approaches in Australia in the 1990s and 2000s included aspirations towards a 'comprehensive, adequate and representative (CAR) system of reserves' (Commonwealth of Australia 1999). This, and advancements in computational tools, led to the adoption of systematic conservation planning approaches by several government agencies.

In this study I focus on two landmark examples, forest agreements in North East New South Wales, which kickstarted the use of the planning software C-Plan (Pressey et al. 2009), and the Representative Areas Program (RAP) in the Great Barrier Reef Marine Park, which popularised the software Marxan (Ball & Possingham 2000). My intention was not to directly compare the case studies, but to showcase them as informative examples which have been in place for long enough to potentially have had meaningful evaluation of their outcomes. The availability of literature and documentation (including assessments of aspects of each planning process (Pressey et al. 2002; Flint et al. 2004; Fernandes et al. 2005; Gunn et al. 2010; Macintosh et al. 2010), as well as accessibility of key participants, were important considerations in case study selection.

Additional detail regarding the interview methods

Interviewer positionality

The structure of this study and choice to undertake key informant interviews reflects my personal interest in how conservation policies are shaped by influential stakeholders and the relative role of scientific advice and knowledge during this process. An underlying assumption was that non-scientific stakeholders would have access to different information and perceive the role of scientific inputs as less influential. I have experience working in environmental policy and conservation practice in Australia and have contacts who provided initial introductions in relation to both case studies.

The people who chose to speak with me and the information they shared is likely to reflect the fact I was independent of any Australian institution at the time and approached my interviewees as a young researcher from a respected university, keen and eager to learn. The fact I am Australian, with familiarity with the case study contexts and management challenges and that I was often introduced to my interviewees by an existing contact of theirs, added to the potential openness of responses. In addition, many interviewees had a personal interest in sharing their story given the significant role these events played in their lives.

Challenges and opportunities with retrospective interviews

In both case studies there were a small number of relevant individuals I was unable to interview, either because I could not locate current contact details, they did not reply to my invitations to interview or they had passed away since the planning process. There are many others with a great deal of knowledge and expertise about these case studies, however the novel objective here was to present the views of senior decision makers at the time. Requesting my interviewees to reflect on events a decade or more ago made the interviews highly susceptible to bias (Selwyn 2013), therefore document analysis was undertaken to verify key claims and to clarify timelines and procedural information.

Another dimension that was an important consideration during interviews and in my subsequent interpretation of interviewee responses, was what interviewees have gone on to do since the planning process. Some had moved between related sectors (e.g. out of the public service, into environmental activism or into politics), others were still in similar roles in the same organisations, and others having retired or left related sectors altogether. Their degree of involvement with conservation planning programs and management challenges since clearly shaped responses, and the state of the Great Barrier Reef and NSW forests was also at the front of many minds.

My interviewees had difficulty naming specific Queensland Government and Federal Government staff they remembered having been involved, and suggested representatives of Indigenous Australian did not play a major role in high level negotiations. Given my focus on key influencers, those who had prominent roles were more likely to have been recommended

and interviewed based on snowball sampling, although I attempted to follow up where other participants had been listed in procedural documentation. Furthermore, those who were still in an ongoing role linked to the case study in question were less candid than those who were retired or independent. All seemed very keen to establish and share their personal legacies, reflecting both the significance of events to their careers, and the tendency towards assertiveness in Australian culture.

Another dimension to conducting retrospective interviews is the influence of hindsight and group-think to arise as people discuss their interpretations of events, especially within any one organisation or sector. One evaluator I interviewed reported this had been true even five years after plan completion. In my analysis I was very conscious to avoid over emphasising any one view point and attempted to reach a wide range of interviewees rather than many from one sector (even though they may have been more easily accessible).

This study was focused on senior decision makers on the assumption they would have the greatest awareness of the factors which shaped the eventual form of the plans and be heavily invested in the consequences of the plans. They were often in positions of responsibility for commissioning or requesting monitoring (rather than undertaking it themselves) so were deemed to have valuable insights into the factors which facilitate or hinder evaluation. Hence the material presented here will not have mentioned all related monitoring exercises, nor will it reflect the perceptions of effectiveness held by members of the general public or other reef or forest users.

6.1 List of papers published, conferences attended, and presentations delivered

Published papers included in this thesis

McIntosh EJ, Pressey RL, Lloyd S, Smith RJ, Grenyer R. 2017. The impact of systematic conservation planning. Annual Review of Environment and Resources 42:677–97.

McIntosh EJ, McKinnon MC, Pressey RL, Grenyer R. 2016. What is the extent and distribution of evidence on conservation outcomes of systematic conservation planning around the globe? A systematic map protocol. Environmental Evidence 5:1–13.

Kohl C, McIntosh EJ, Unger S, Haddaway N, Kecke S, Schiemann J, Wilhelm R. 2018. Online tools supporting the conduct and reporting of systematic reviews and systematic maps: a case study on CADIMA and review of existing tools. Environmental Evidence 7:e1-17.

McIntosh EJ, Chapman S, Kearney SG, Williams B, Althor G, Thorn JPR, Pressey RL, McKinnon MC, Grenyer R. (2018). Absence of evidence for the conservation outcomes of systematic conservation planning around the globe: A systematic map. Environmental Evidence, 7:22.

Submitted papers included in this thesis

McIntosh, E.J. n.d. Barriers to the evaluation of systematic conservation plans: Insights from landmark Australian plans. Biological Conservation (submitted).

Other publications related to this research

Westgate MJ, Haddaway NR, Cheng SH, McIntosh EJ, Marshall C, Lindenmayer DB. 2018. Software support for environmental evidence synthesis. Nature Ecology & Evolution 2:588–590.

Sinclair SP, Milner-Gulland EJ, Smith RJ, McIntosh EJ, Possingham H, Vercammen A, Knight AT. 2018. The use, and usefulness, of spatial conservation prioritisations. Conservation Letters e12459:1–7.

Unrelated publications during this period

McIntosh EJ, Rolfe J, Pinto U, Kirkwood J, Poiner IR. (n.d.). Designing report cards for aquatic health with a whole-of-system approach: Gladstone Harbour in the Great Barrier Reef. Environmental Indicators, in review.

Conferences attended, and presentations delivered during my DPhil

Absence of evidence for outcomes of systematic conservation planning (oral presentation & poster). *5th European Congress of Conservation Biology.* Jyväskylä, Finland, 12-15 June 2018.

Absence of evidence for outcomes of systematic conservation planning (poster). *Safeguarding space for nature and securing our future: developing a post-2020 strategy*. Zoological Society of London, 27-28 February 2017.

Finding the needle in the haystack: Evidence for the effectiveness of a complex conservation intervention (poster). *Student Conference on Conservation Science*. Cambridge, 28-30 March 2017.

Overcoming conflicts between coastal development and World Heritage values in Central Queensland (oral presentation). *10th Annual Ocean Policy Symposium*. Oxford, 10 February 2017.

Towards systematic conservation planning in the New Forest (oral presentation). *Ecology and management of the New Forest in an era of climate change*. Lyndhurst, 25 October 2016.

Experience collating evidence of conservation outcomes when rigorous evaluations are rare (oral presentation). *The first international conference of the Collaboration for Environmental Evidence*. Stockholm, 25-27 August 2016.

Evidence for the impacts and outcomes of systematic conservation planning around the globe – a systematic map (oral presentation). *Society for Conservation Biology 4th Oceania Congress*. Brisbane, 5-8 July 2016.

Trade-offs in a complex socio-ecological system: Long term planning in the New Forest, southern England (poster). *Joint BES and CCI Annual Symposium*. Cambridge, 11-13 April 2016.

Conservation planning and the future of our natural world (oral presentation). *The Change Agenda: Inaugural John Monash Scholars' Symposium*. Oxford, 31 March – 1 April 2016.

Trade-offs in a complex socio-ecological system: Long term planning in the New Forest, southern England (poster). *Student Conference on Conservation Science*. Cambridge, 22-24 March 2016.

Ministerial workshops to shape the 25-year Environment Plan. Department for Environment, Food & Rural Affairs, London. 4 November 2015.

Spatial conservation planning for the UK. York, 23 September 2015.

Systematic conservation planning workshop. Imperial College, Silwood Park, 10-12 August 2015.

Evaluating conservation planning success: Addressing the societal and governance factors behind effective conservation actions (oral presentation). *27th International Congress for Conservation Biology and 4th European Congress for Conservation Biology*. Montpellier, 2-6 August 2015.

The conservation science/policy interface: Challenges and opportunities. Zoological Society of London, 16 April 2015.

Student Conference on Conservation Science. Cambridge, 26-26 March 2015.

Biosymposium 2015: The Functions and Values of Biodiversity. Oxford, 6-7 January 2015.

Joint 2014 Annual Meeting. British Ecological Society and Société Française d'Ecologie. Lille, 9-12 December 2014.

6.2 Co-author statements

THE UNIVERSITY OF QUEENSLAND AUSTRALIA | NOT IF, WHEN.
THE CAMPAIGN TO CREATE CHANGE

Prof Dariusz Wójcik
Director of Graduate Studies (Research)
School of Geography and the Environment
University of Oxford
16/07/2018

Dear Professor Wójcik,

I can confirm that I co-authored the following paper with Emma J McIntosh and support her submitting it as part of her DPhil thesis. A simple majority of this work was carried out by Emma.

McIntosh, E.J., Chapman, S., Kearney, S.G., Williams, B., Althor, G., Thorn, J.P.R., Pressey, R.L., McKinnon, M.C., Grenyer, R., n.d. Absence of evidence for the conservation outcomes of systematic conservation planning around the globe: A systematic map. Environ. Evid. (in review)

This study was led by EJM. The research question was originally conceived by MCM and RLP, who advised throughout the project. Title screening was conducted by EJM and SC, abstract screening by EJM, SC, SGK, BW, GA and JPRT, and full-text screening by EJM, SC and SGK. Full-text coding was conducted by EJM and BW. RG advised on the design and execution of the study. All authors read and approved the final manuscript.

Yours sincerely,

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Prof Dariusz Wójcik
Director of Graduate Studies (Research)
School of Geography and the Environment
University of Oxford

16th July, 2018

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Yours sincerely,

Sarah Chapman

Sarah Chapman
PhD Candidate
University of Queensland
School of Earth and Environmental Sciences

Prof Dariusz Wójcik
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23rd July 2018

Dear Professor Wójcik,

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McIntosh, E.J., Pressey, R.L., Lloyd, S., Smith, R.J., Grenyer, R., 2017. The impact of systematic conservation planning. Annu. Rev. Environ. Resour. 42, 677–97. https://doi.org/10.1146/annurev-environ-102016-060902
EJM led and drafted the manuscript, RLP, SL, RJS and RG contributed conceptual ideas and contributed to the writing of the text. All authors read and approved the final manuscript.

McIntosh, E.J., McKinnon, M.C., Pressey, R.L., Grenyer, R., 2016. What is the extent and distribution of evidence on conservation outcomes of systematic conservation planning around the globe? A systematic map protocol. Environ. Evid. 5, 1–13. https://doi.org/10.1186/s13750-016-0069-4
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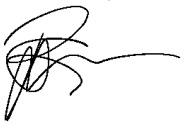
Yours sincerely,



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16/07/18

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CK drafted the CADIMA part of the manuscript, EJM performed the review of software tools and drafted the associated parts of the manuscript, SU was responsible for the programming of CADIMA and all authors contributed to the final manuscript. All authors read and approved the final manuscript.

Yours sincerely,

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Yours sincerely,

Christian Kohl

Stefan Unger

Steffen Kecke

Joachim Schiemann

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16 July 2018

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Yours sincerely,

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August 7 2018

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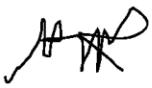

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19 July 2018

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EJM led and drafted the manuscript, RLP, SL, RJS and RG contributed conceptual ideas and contributed to the writing of the text. All authors read and approved the final manuscript.

McIntosh, E.J., McKinnon, M.C., Pressey, R.L., Grenyer, R., 2016. What is the extent and distribution of evidence on conservation outcomes of systematic conservation planning around the globe? A systematic map protocol. Environ. Evid. 5, 1–13. https://doi.org/10.1186/s13750-016-0069-4

EJM led and drafted this manuscript. MCM and RLP initially conceived of a map and EJM and MCM subsequently designed this version of the study. EJM, MCM and RG co-authored the manuscript. RLP provided input on terminology and inclusion/exclusion criteria. All authors read and approved the final manuscript.

McIntosh, E.J., Chapman, S., Kearney, S.G., Williams, B., Althor, G., Thorn, J.P.R., Pressey, R.L., McKinnon, M.C., Grenyer, R., n.d. Absence of evidence for the conservation outcomes of systematic conservation planning around the globe: A systematic map. Environ. Evid. (in review)

This study was led by EJM. The research question was originally conceived by MCM and RLP, who advised throughout the project. Title screening was conducted by EJM and SC, abstract screening by EJM, SC, SGK, BW, GA and JPRT, and full-text screening by EJM, SC and SGK. Full-text coding was conducted by EJM and BW. RG advised on the design and execution of the study. All authors read and approved the final manuscript.

Yours sincerely,

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SS

Thu 19/07/2018 09:42

Samuel Sinclair

Authorship confirmation

To Emma McIntosh

Cc samuelpsinclair@gmail.com

Dear Professor Wójcik,

I can confirm that I co-authored the following paper with Emma J McIntosh and support her submitting it as part of her DPhil thesis. A simple majority of this work was carried out by Emma.

McIntosh, E.J., Pressey, R.L., Lloyd, S., Smith, R.J., Grenyer, R., 2017. The impact of systematic conservation planning. Annu. Rev. Environ. Resour. 42, 677–97. https://doi.org/10.1146/annurev-environ-102016-060902

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Yours sincerely,

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18th July 2018

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Director of Graduate Studies (Research)
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University of Oxford

Dear Professor Wójcik,

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Yours sincerely,

Bob Smith

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ETH Zürich

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14th July 2018

Dear Professor Wójcik,

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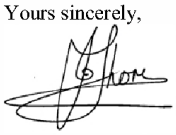
Yours sincerely,



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16/07/2018

Dear Professor Wójcik,

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Yours sincerely,

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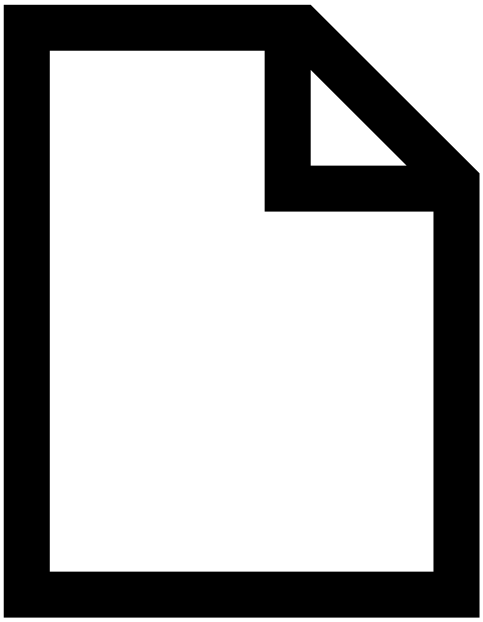

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