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REVIEW

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10 years of decision-making for biodiversity conservation actions: A systematic literature review

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Abstract

Decision science emphasizes necessary elements required for robust decision-making. By incorporating decision science principles, frameworks, and tools, it has been demonstrated that decision-makers can increase the chances of achieving conservation aims. Setting measurable objectives, clearly documenting assumptions about the impact of available actions on a specific threat or problem, explicitly considering constraints, exploring and characterizing uncertainty, and structured deliberation on trade-offs have been identified as key elements of successful decision-making. We quantify the extent to which these five elements were utilized in published examples of decision making in conservation in both academic and conservation practice between 2009 and 2018. We found that less than 50% of identified examples included all five elements, with differences in the degree of decision science applied across five commonly used decision support approaches: adaptive management (AM), systematic conservation planning (SCP), structured decision making (SDM), multi-criteria decision analysis, and cost-effectiveness analysis. Example applications that utilized the SDM framework were limited in numbers but used on average more than 50% of the five key elements we considered. Although SCP and AM constituted the majority of examples, they were more prevalent in academic studies rather than management applications. SCP and AM examples were widespread in protected area planning, threat abatement, and restoration. Strong geographic bias exists in documented conservation activities that deploy all five decision science elements.

KEYWORDS

adaptive management, conservation planning, cost-effectiveness analysis, decision theory, multi-criteria decision analysis, structured decision making, systematic conservation planning

1 | INTRODUCTION

Despite the substantial effort and investment into the conservation of species and ecosystems, biodiversity loss is accelerating (C. N. Johnson et al., 2017). The list of threatened species keeps growing, with over a million species threatened by extinction, and many species expected to be lost within two decades (Díaz et al., 2019; WWF 2020). Global assessments have identified comparatively few successful management examples that led to the down-listing of species' extinction risk (Bolam et al., 2021; Hoffmann et al., 2010). Most national and international environmental strategies fall short of their nominal targets and many report worsening trajectories for monitored species (McDonald et al., 2015; Secretariat of the Convention on Biological Diversity, 2020; Tittensor et al., 2014). It is not possible to determine to which extent the strategies developed to stem biodiversity decline are flawed or sound, or whether they are implemented at too small a scale or with inadequate resources. If important insights from decision-science are neglected during planning, the risk of failure and the possibility of perverse or unintended consequences increases (Bode et al., 2015; Devillers et al., 2015; Game et al., 2013; Hervé et al., 2016; Renwick et al., 2015). Existing evidence across multiple disciplines including medicine and public policy including environmental policy shows that structured processes based on decision science lead to a better understanding of the problem at hand, sound evaluation of available options, and the trade-offs between them (Arvai et al., 2001; Bekker et al., 2003; Herek et al., 1987; Schafer & Crichlow, 2002). Principles of decision science have been used to assess other aspects of conservation applications, such as ecological indicators (Watermeyer et al., 2021). Recent publications call for greater attention to be given to fundamental principles in conservation plans to increase the chances of achieving urgently needed conservation outcomes (Adams et al., 2019; Kellon & Arvai, 2011; Leclère et al., 2020; Maron et al., 2021; Rose et al., 2019).

1.1 | Decision support approaches used in conservation

A range of decision support approaches and tools exist to guide conservation decisions (Acosta et al., 2016; Bower et al., 2018; Schwartz et al., 2018). Frequently used frameworks include systematic conservation planning (SCP), adaptive management (AM), and structured decision making (SDM), and frequently used stand-alone prioritization concepts include multi-criteria decision analysis (MCDA) and cost-effectiveness analysis (CE). These differ in key aspects (Table 1) due to their evolution and use in different contexts. Moreover, the use of any given framework or approach does not ensure that all of the key elements of sound decision-making are incorporated in any given decision (Game et al., 2013; Gregory et al., 2012; Kahneman & Tversky, 1984; Wilson et al., 2006; Wilson et al., 2007).

Each of the five commonly used options in Table 1 utilizes distinct steps in the decision-making stage of planning processes. These steps aim to ensure important elements are included to decrease the risk of not meeting objectives (Nicholson & Possingham, 2006). Most frameworks describe steps at a high level, such as defining objectives or developing alternatives. This recognizes that each decision context may require a tailored approach or tool to be used in each phase. While vagueness within decision support options provides flexibility to account for context, it can lead to unintended neglect of the key steps.

Based on fundamental decision theory texts in the context of conservation (Gregory et al., 2012), we identify

TABLE 1 Frameworks and prioritization concepts that are frequently used to support decisions for conservation management strategies.

Framework/ prioritization concept	Key aspects	Key reference
Systematic conservation planning	– Spatially explicit planning for protected areas – Map as output – Based on selection of distinct planning units	Margules and Pressey (2000); Moilanen et al. (2009)
Adaptive management	– Monitoring information used to adjust repeated decisions – Experimental set up – Learning about effect of management intended	Keith et al. (2011)
Structured decision making	– Importance on clarifying decision problem and eliciting appropriate objectives and metrics – Explicit comparison of alternatives – Often with transparent quantification of trade-offs	Gregory et al. (2012)
Multi-criteria decision analysis	– Focus on relative importance of different objectives – Scoring, weighting, and summation of different criteria and/or objectives to rank options	Adem Esmail and Geneletti (2018)
Cost-effectiveness analysis	Consideration of cost without compromising objectives other than cost: comparison based on return of investment	Wilson et al. (2009)

TABLE 2 Assessed categories that were classified within this literature review.

Five elements for robust decision-making	Classification (presence/absence)
Objectives	Are environmental objectives quantitatively expressed?
Actions and threats linked in a theory of change	Is there a clear link to a threatening process? Examples were classified based on Salafsky et al. (2008). As conservation actions aim in most cases to mitigate existing threats that cause a decline or deterioration, we focused on the inclusion of a specific threat as proof of an existing theory of change in the decision-making process.
Socioeconomic considerations	Are socioeconomic objectives included? Only examples that included a specific objective regarding social or economic factors that were considered in the choice between options were classified as "socioeconomic objectives present."
Sensitivity and uncertainty analyses	Are sensitivity or scenario analyses done to test for effects of uncertainty?
Trade-offs	Are trade-offs between different objectives described and explored? Only examples that used trade-offs to make a choice between options were classified as "trade-off present."
Four descriptive factors	**Multiple entries possible**
Decision support option	Five frameworks and prioritization strategies, or "mixed" if more than one was used (Table 1)
Context	If collaboration with management authorities or implementation were explicitly described: "conservation practice", if not: "academic"
Type of management	Five types of proposed management actions based on Salafsky et al. (2008)
Location	Country in which proposed management was located

five crucial elements of a robust decision process against which to evaluate published descriptions of conservation focused decision processes: (1) identify clear objectives, (2) identify measures of anticipated impacts of planned actions with a clear theory of change, (3) document financial and social constraints, (4) characterize uncertainties and conduct sensitivity or uncertainty analysis, and (5) characterize and measure trade-offs. Evidence of the importance of these five decision elements is discussed in more detail in Supplementary Material S1 in Data S1. The five critical elements of decision making that we highlight here have been highlighted as critical in decision-making among wildlife managers (Fuller et al., 2020).

1.2 | Evaluating decision processes in conservation

Recent studies that identify the factors leading to success and failure of decisions made in conservation management include strong recommendations for evidence-based conservation (Sutherland et al., 2020; Sutherland et al., 2004), the creation of data repositories (https://www.miradishare.org/ux/home, https://www.conservationevidence.com, https://marinescp.jcu.io), and reviews that provide an overview of conservation management effectiveness (Bayraktarov et al., 2016; Geldmann et al., 2018; McIntosh et al., 2018). Attempts to quantify the effectiveness of implemented conservation plans by measuring outcomes have largely failed to produce definitive findings due to mixed evidence (Edgar et al., 2014), data paucity (McIntosh et al., 2018), and high variability between conservation contexts (Lester et al., 2009). However, the importance of sound decision-making is widely accepted (Butt et al., 2020; Carwardine et al., 2019; Visconti & Joppa, 2015; Wilson et al., 2006). The damaging effects of neglecting elements of good decision-making during planning are well documented. Failure to identify meaningful objectives (Bond et al., 2008; Game et al., 2013), missing theory of change as link between actions and threats (Kuempel et al., 2019), failure to include constraints such as costs or feasibility (Symes et al., 2016), or failure to conduct sensitivity analysis to evaluate uncertainty (Larson et al., 2016; Mazor et al., 2014; Runge et al., 2016; Sutton & Armsworth, 2014) can lead to suboptimal or counterproductive decisions. A systematic assessment of decision-making for conservation actions can identify the degree to which the key elements of sound decision-making are being utilized in conservation planning and management.

Here we provide a comparative and quantitative review of the extent to which the elements of decision-making are utilized in published work on conservation decisions problems. Our review is based on 466 examples drawn from the peer-reviewed literature and provides insight into the types of conservation decisions that benefit from the application of all elements set out in decision theory. We discuss the elements of decision-making that might need to be bolstered to produce more robust conservation decisions and better outcomes.

2 | METHODS

2.1 | Data collection

We use a systematic review protocol (Moher et al., 2009) through a keyword search of the Web of Science, targeting literature published between 2009 and 2018. Our goal was to find documents describing decision-making that selects a strategy from a range of options to address a specific environmental problem. A search was conducted in December 2018, using the term "decision-making" and five common decision-aiding frameworks (Bower et al., 2018; Schwartz et al., 2018) and prioritization methods (Supplementary Material S2 in Data S1). Our search yielded 7106 publications, which were subsequently screened for a conservation-related decision-context, resulting in 1218 publications that were read in detail. Of these, 466 examples described a decision process of prioritizing management strategies in adequate detail to understand the decision process, and information on five decision elements and four descriptive factors was collected from each (Table 2). If a publication described examples of different decisions, each individual decision was recorded as one example (see, e.g., Canessa et al., 2016). If case-studies were referred to with citation, they were excluded to avoid redundancy. Horizon Scanning and Strategic Foresight (Cook et al., 2014) had been initially included in the search but were not part of the analysis as no example was found that described a conservation-related decision between available management options.

Table S3 in Data S1 provides full information on the coding scheme. All code and data are available on figshare (https://doi.org/10.6084/m9.figshare.17205713.v1).

2.2 | Reliability of data classification

Several measures were taken to improve clarity of categories and to identify errors and variation in the data classification. Extraction of qualitative information from text is not free from bias and errors (Marcoci et al., 2019; McHugh, 2012). It is common that highly trained experts come to different conclusions when faced with the same evidence (Kahneman et al., 2021). Such unwanted variability in judgments can have a greater impact than bias. This variability is to be expected when classifying text and can be explored by quantifying variability across multiple raters. We assessed the reliability of the extracted data using 25 examples (Supplementary Material S4 in Data S1). Percent agreement between four additional raters and the lead author was well above conventional thresholds of 75% for inter-rater-reliability-testing for all categories. The error rate of the main rater was lower than the additional raters.

3 | RESULTS

3.1 | A profile of conservation decisions

Our quantitative analysis included 466 examples (Tables S5 and S9 in Data S1). About a third of the 466 examples described either a collaboration with authorities that were interested in finding a solution to a particular conservation problem or partial or full implementation at the time of publishing (128 examples, referred to as "conservation practice" in the following). Two thirds (338 examples) have been conducted without any indication that decisions were implemented by a practitioner, manager, or agency (referred to as "academic" in the following). The numbers of examples for different decision support approaches were biased toward SCP (212) and AM (106), while all other, as well as mixed approaches, contributed 29–47 examples each (Figure 2, Table S5 in Data S1).

We found a clear difference in how often the five key decision elements were used overall and in combination. The description of only one of the elements was rare in both academic and conservation practice contexts. In academic contexts, the combination of three or four elements was more than twice as likely as the combination of two or five elements. In conservation practice contexts, numbers of examples that combined two, three, four, or five elements were similar (Figure 1). In total, less than half of all examples (211 examples: 52% of conservation practice and 37% of academic examples) used more than three of the important decision elements in combination. The relative frequency of examples with five elements was slightly higher in conservation practice contexts. When three elements were combined, trade-off, link to threat through a theory of change and socioeconomic constraints were more often missing than quantitative objectives or sensitivity analysis. When four elements were combined, 95 examples excluded trade-offs and 21 linking to a threat through a theory of change, while the other elements were less often missing. Only 27% of all examples explicitly documented deliberation on trade-offs. Each of the other elements was described in 70%–84% of examples.

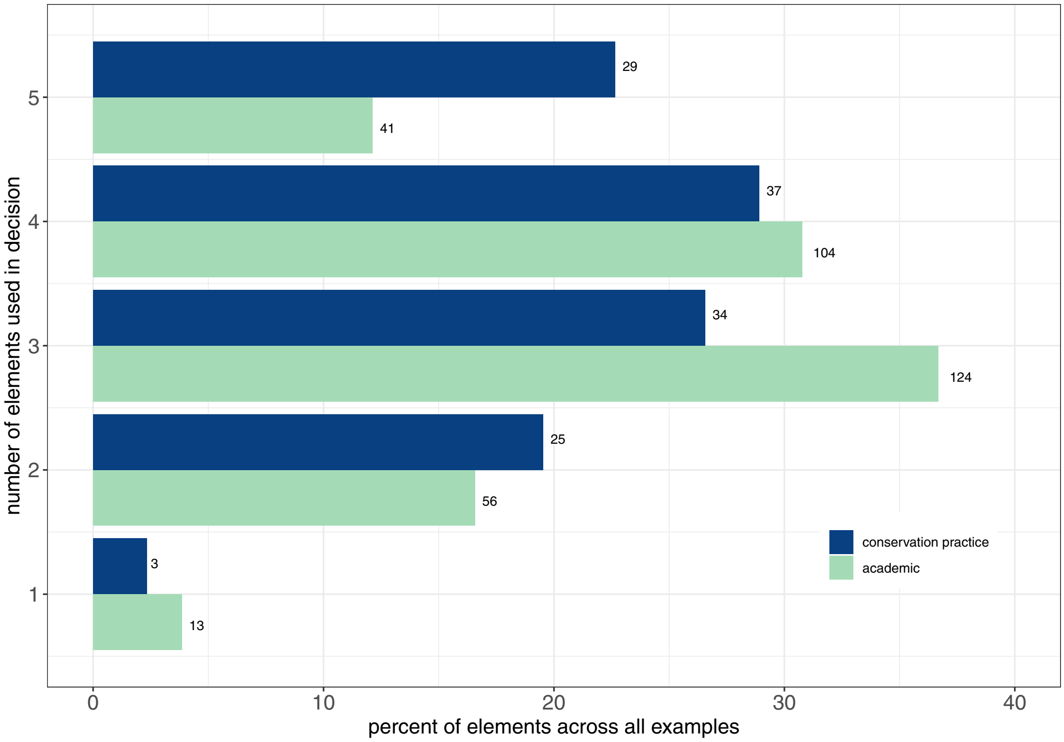

FIGURE 1 Number and proportion of key decision elements that are described in academic and conservation practice contexts.

We found clear differences when comparing how often specific decision support options were used in academic or conservation practice contexts and how often each used the five different elements (Figure 1 and Figure 2). AM was the most often used decision support approach in conservation practice contexts and the second most often used in academic contexts (Figure 2). Only a few of these examples used all five decision elements in combination, and a large fraction used only two or three elements. Quantitative objective and socioeconomic objectives were not described in approximately half of the academic and conservation practice examples.

SCP comprised the largest fraction of examples in academic studies (Figure 2a). Half of these examples did not describe a clear link to a threat through a theory of change, and a third did not include any socioeconomic objectives (Figure 2c). There were far fewer examples of SCP in conservation practice contexts, and in those examples, a relatively low proportion clearly described a theory of change that links management to a threat and conducted sensitivity analysis. In contrast, a higher proportion of applications considered documented socioeconomic objectives (Figure 2c). A higher fraction of SCP examples used five elements in conservation practice contexts than in academic contexts. At the same time, almost a quarter of the conservation practice examples for this framework used only one or two elements (Figure 2b).

SDM was the only framework that was used predominantly in a conservation practice setting (74%), while over 60% of examples of each of the other decision support strategies were set in an academic context (Figure 2a). Conservation practice examples of SDM had high inclusion rates for all elements. Academic examples of SDM included socioeconomic objectives less often (Figure 2c).

Compared to other decision support options, examples of MCDA rarely articulated a quantitative objective in both conservation practice and academic contexts. About a third of academic examples that used CE did not describe quantitative objectives for the biodiversity value that was supposed to benefit from the management, and a third of conservation practice examples that used CE did not describe any sensitivity analysis or other exploration of uncertainty.

SDM described all five elements in 28% of examples, compared to 24% of CE examples, 19% examples with mixed decision support, 15% of SCP examples, 12% of MCDA examples, and 7% of AM examples (Figure 2a). To account for the rare use of trade-offs, we tested a relaxed condition for including them, with similar results (Figure 2a). There was no visible temporal trend for the frequency of using four or five elements in any of the frameworks (Supplementary Material S6 in Data S1).

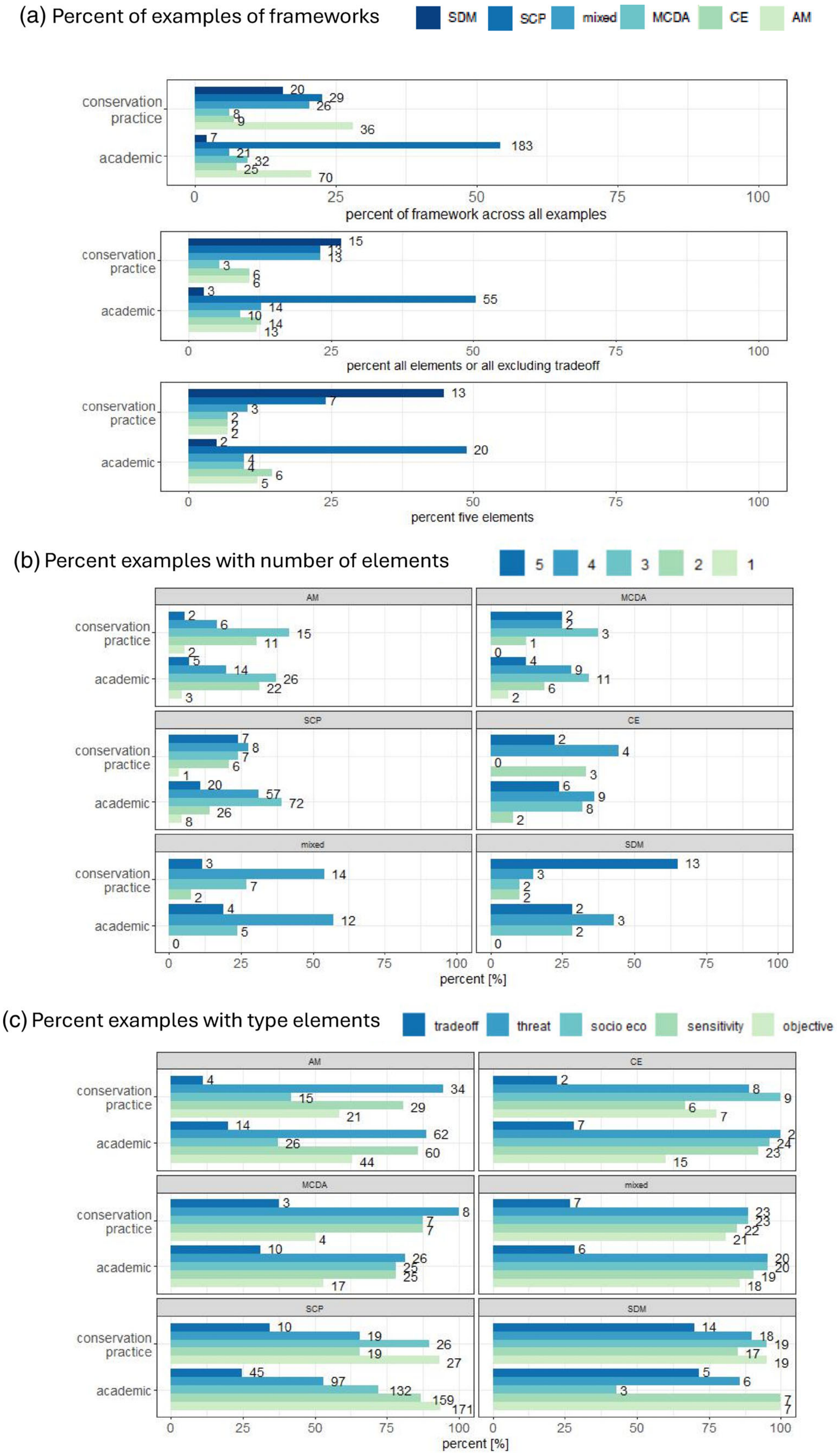

FIGURE 2 (a) The use of frameworks in conservation practice and academic contexts in general (top row) and in examples that use all elements (bottom row). The middle row shows the examples that use either all elements or exclude only trade-offs. The *x*-axis shows percent within each group of academic and conservation practice examples. Each bar is labeled with the number of examples. (b) The use of elements within each framework in conservation practice and academic contexts. The *x*-axis shows percent within each framework of academic and conservation practice examples. Each bar is labeled with the number of examples. (c) The use of specific elements within each framework in conservation practice and academic contexts. The *x*-axis shows percent within each framework of academic and conservation practice examples. Each bar is labeled with the number of examples.

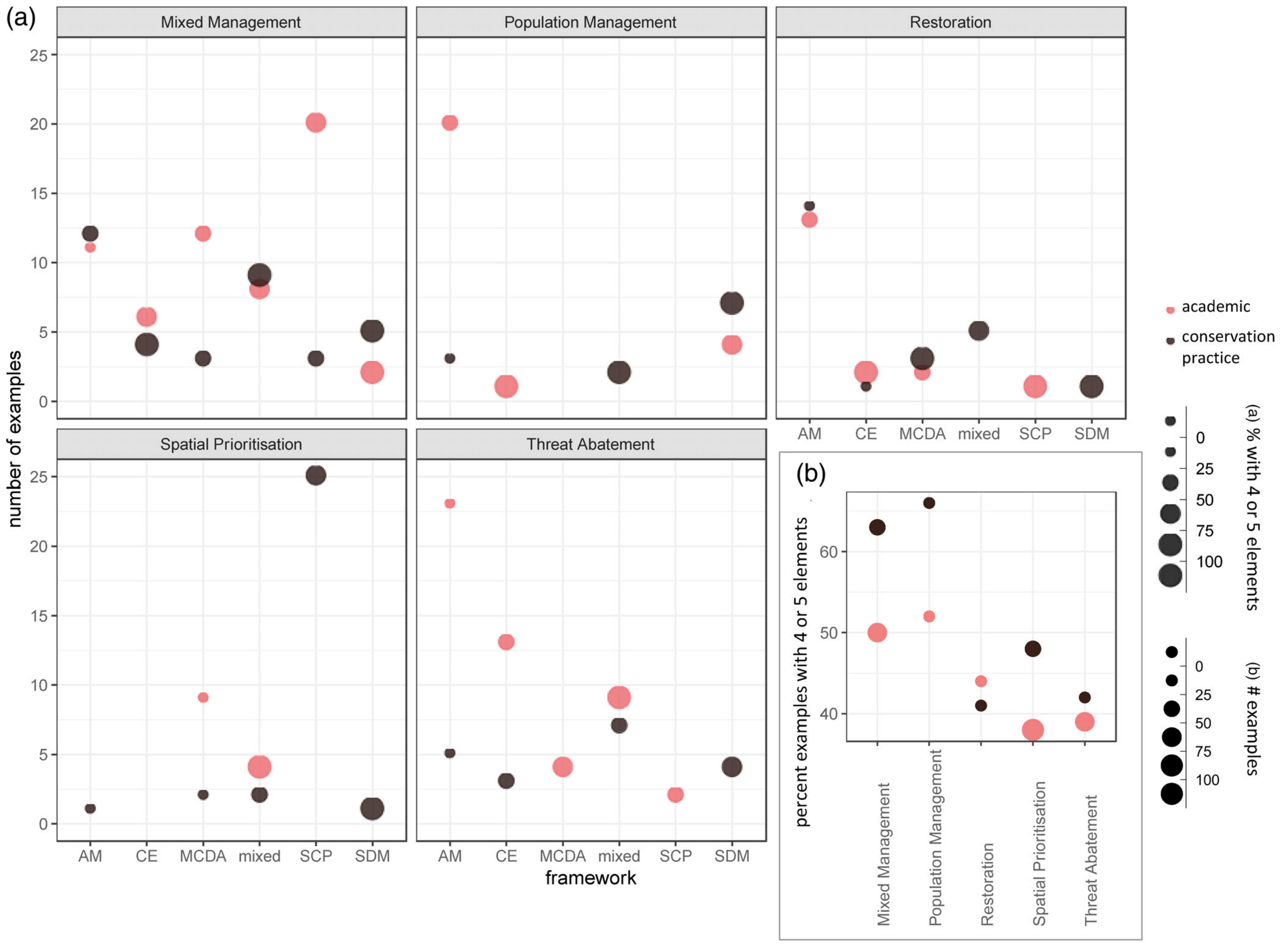

FIGURE 3 Panel (a): Bubble plot of how often different frameworks were used in academic and conservation practice examples for different types of management. The *y*-axis shows the number of examples, while the size of the points represents the fraction [%] that used four or five elements. Note that in order to visualize differences in the numbers along the *y*-axis, the high number of examples that use systematic conservation planning for spatial prioritization is only shown in panel (b). Panel (b): The frequency of using all five elements within different management types ranges from 38% to 66%, with spatial prioritization and threat abatement in academic contexts at the lower end and population management and mixed management in conservation practice context at the higher end.

3.2 | Application of all elements of decision-making within different types of conservation problems

Particular frameworks were preferred for specific types of conservation problems. Several patterns emerged in the analysis of how often more than three elements were included in each type of management in conservation practice and academic contexts (Figure 3).

Decisions were made most often within preselected management strategies (see different panels in Figure 3). Only about a quarter of all examples (95 out of 466) considered more than one management strategy in the decision-making process ("mixed" box in Figure 3a). The majority of examples considered options for one predetermined strategy exclusively (202 spatial prioritization [including protected area planning], 70 threat abatement, 42 restoration, and 27 population management). The most common mixed combinations were spatial prioritization and restoration (26 examples), threat abatement and population management (14 examples), and threat abatement and restoration (13 examples). Seventeen examples did not match the five management categories.

Some frameworks were found more often for a specific type of management than other frameworks (differences of height of bubbles in each panel): While examples for mixed management can be found for all frameworks, spatial prioritization was most often conducted with SCP, and most decisions on restoration were made within an AM framework.

Some frameworks were utilized differently in academic and conservation practice contexts (see difference in height for each color): mixed management examples in academic contexts used most often MCDA and SCP, but mixed management examples in conservation practice contexts used all other frameworks more often. Examples for population management and threat abatement in academic contexts used most often AM, while the same type of management in conservation practice contexts used frequently other frameworks.

Some types of management were particularly prone to decision-making with a low number of decision elements (smaller points that are higher up along the *y*-axis in each panel and lower points in plot 3b). For example, restoration and mixed management examples used AM often in both conservation practice and academic contexts, but these examples included four or five elements at a lower rate than MCDA or mixed approaches. Academic population management examples used most often AM, with a lower frequency of using four or five criteria than among the fewer examples of CE or SDM. Population management examples used mixed frameworks or SDM as often in conservation practice contexts as AM and included four or five elements more frequently. Panel b in Figure 3 shows that decision-making for threat abatement and restoration was more prone to omit two or more elements both in academic and conservation practice contexts, and spatial prioritization in academic examples used least often more than three of the key elements.

To be sure the likelihood of including all elements was influenced by specific decision support options and not driven by specific authors, particularly for decision support options with fewer examples, a coauthor network was created for all examples that used five elements. The network (Figure S7 in Data S1) shows a high diversity of authors in general for all decision support options, with one large network of authors of academic examples who are connected through the Centre of Excellence for Environmental Decisions in Australia.

3.3 | Geographic distribution of examples and use of decision elements

Although examples of conservation decisions existed for over 80 countries across all continents, the location of the examples was biased toward the United States and Australia. The two countries provided more than a third of all examples overall, as well as for academic and conservation practice contexts individually (Figure S8 in Data S1). Academic examples were found for 52 countries and conservation practice examples for 33 countries. However, there were only six countries with more than two conservation practice examples, and no conservation practice examples were found for most African, Middle Eastern, and Latin American countries.

4 | DISCUSSION

We have shown that robust conservation decisions according to standards of decision science exist across all decision support options in academic and applied contexts. But the bulk of academic and applied studies that document decisions that we evaluated in this study do not apply all of the key elements of decision science, or at least did not report them. We found differences in the use of decision elements between decision support tools in academic and applied contexts and across different management activities. Our results imply that problems that stem from omitting specific key elements, including risking further species' declines when the planning lacks quantitative and ecological meaningful objectives (Carwardine et al., 2009; Game et al., 2013; Pfab et al., 2011), implementing actions that do not address the key threats (Bayraktarov et al., 2016; Devillers et al., 2015), or creating socioeconomic problems when not acknowledging the human context during the planning (Bode et al., 2010; Wittemyer et al., 2008), are likely to be common across the conservation discipline.

Of the decision support frameworks we considered, SDM is the most recently developed framework, and therefore draws on the most complete suite of insights from decision science. Although applications of SDM most often included many elements, they were also the most underrepresented in our database and almost exclusively from the United States. We believe our results provide great insights into the potential shortcomings affecting decision-making and highlight opportunities for more transparent reporting of important decision elements in publications.

The type of decision support that was used during decision-making contributed more to the differences in the uptake of key elements than whether the activity was academic or applied. There were clear signs that some conservation management strategies are most likely to be at risk of failing to achieve ecologically meaningful benefits due to a propensity to omit key elements of the decision-making process.

4.1 | Consequences of limited consideration of decision elements in protected area planning

It has been shown over 10 years ago that the locations of protected areas are biased toward places that do not face a threat of land conversion (Joppa & Pfaff, 2009), and many publications have discussed the shortcomings of protected areas as a tool to protect biodiversity (Barnes et al., 2018; Cooke et al., 2023; Mora & Sale, 2011; Naumann et al., 2021; Pressey et al., 2017). These discussions focus particularly on threatening processes, and if and how they are included in the planning. Our results show that it is still not common practice to include a clear description of key threats and the expected mechanism of mitigation in publications of SCP. Similar evidence has been published in an EU context (Hermoso et al., 2022).

If our results are representative of SCP in the real world, many of the protected areas could have limited potential to protect biodiversity from existing threats if they were implemented because lower opportunity costs cause a bias toward prioritizing areas with low or no threat pressure. The rezoning of the Great Barrier Reef is a famous example of this particular problem in protected area planning. Shortly after the plans had been made public, critical voices highlighted the limited benefits in terms of protection from threats to biodiversity, due to the spatial exclusion of commercial fishing areas (Devillers et al., 2015). While planning without a clear conceptual link between the intensity of threats in spatial planning units minimizes opportunity costs and facilitates implementation by reducing conflicts with resource users, protected areas become biased toward locations that are exposed to limited or no threats.

The low rate of socioeconomic objectives in academic studies could be explained by the focus on specific aspects with the aim to show novel approaches in SCP. However, the frequent lack of any sensitivity or scenario analysis in a third of applied examples indicates that addressing uncertainty is not widely considered when making decisions for a protected area. This may lead to conservation area designs that are susceptible to failure of key assumptions about, for example, the location of key species habitats, or how species may respond to changing climates (Moilanen et al., 2006).

4.2 | Consequences of limited use of the full potential of AM for threat abatement and restoration

The lack of quantitative objectives and socioeconomic objectives has been stated as one of the most common mistakes in conservation decision-making (Game et al., 2013). The fact that these key decision elements are often missing in documentation of AM might have broader implications for many restoration and threat abatement projects, as the clear majority of examples that we found for these management strategies used AM for decision support. If AM is primarily used to monitor changes in real-time and practices "learning by doing," often without clear ecological objectives (Carwardine et al., 2009), it is questionable if these projects have the capacity to deliver the intended conservation outcomes (Gregory et al., 2006; Riley & Gregory, 2012). An example from our survey is Briceno et al. who compare interventions against poaching for yellow shouldered parrots but do not provide any quantitative objective regarding the level that poaching needs to be reduced to keep the population at viable levels (Briceño-Linares et al., 2011). The lack of quantitative objectives was also common in decisions based on CE, where often only threats were targeted, without a clear measure of how a reduction of a threat would benefit a species or habitat. Examples included improving water quality to benefit waterfowl with no quantitative objective for the waterfowl (Martin-Ortega et al., 2015), sediment reduction for the Great Barrier Reef without any quantitative objective for reef-related biodiversity (Bouma et al., 2011), or control of an invasive species without a quantitative objective for biodiversity that would benefit from the control (F. A. Johnson et al., 2017). The plain fact that CE is a means to find the best ratio between costs and benefits might explain why targets were often not articulated in more detail, but it highlights how easily important elements of the decision process can get overlooked.

Developing effective AM plans is challenging, resulting in few success stories (Gregory et al., 2006; Riley & Gregory, 2012). Similar to our findings, a recent review of AM found few applied AM projects compared to academic studies (Westgate et al., 2013). The review also suggested that often decisions makers used the 'adaptive management' label when the actual approach did not meet the standards of the theory behind it. This may also explain the low number of described elements in our results (Figures 2 and 3).

Restoration attempts reportedly have a low success rate and often neglect socioeconomic criteria or considerations of threats in a theory of change (Bayraktarov et al., 2016; Suding, 2011; Wortley et al., 2013). Restoration is a key conservation activity worldwide and is fundamental to achieving global biodiversity framework goals (CBD, 2022; Fischer et al., 2021; Strassburg et al., 2020). A greater emphasis on a rigorous decision process, particularly under AM, seems to be a promising pathway to improve success rates.

4.3 | Different preferences of decision support options in applied versus academic examples

SCP and AM are not necessarily the most common decision-aiding support options in the conservation practice, despite their popularity within academic case studies. The dominance of these decision support options in academic contexts might obfuscate important other questions and problems that applied conservation managers are interested in. The misalignment might be partly caused by the ease with which some tools can be used to work on well-established and intellectually interesting problems, like the use of Marxan for the minimum-area/maximum-coverage in spatial planning, or the use of Bayesian-Belief-Systems and Value-of-Information in AM. The high proportion of SDM in conservation practice might be an indication of the usefulness of processes that are more closely linked to decision science in applied contexts.

4.4 | Spatial patterns in decision approaches

Examples in which all five critical elements of decision making were applied were strongly biased toward Australia and the United States. Recent literature reviews on biodiversity confirm the persisting bias in publications toward very few countries, which do not match with the distribution of biodiversity (Di Marco et al., 2017; Wilson et al., 2016). Data gaps in meta-analyses are likely not stemming from a lack of research, but rather from language barriers that prevent existing literature from being visible in major English online repositories (Amano et al., 2023; Amano et al., 2021; Hannah et al., 2024; Konno et al., 2020).

Efforts such as summaries for particular management types are an effective way to make existing efforts visible (Bayraktarov et al., 2020) but are needed on a much larger scale. In the current state, the literature on decision processes for conservation management seems to paint a very limited picture of conservation management decisions around the world.

4.5 | Reasons for limited uptake

Conservation science is not limited to realistic planning but also aims to progress methods and theoretical concepts or reports new data. Therefore, a certain amount of literature on decision processes, particularly in academic contexts, is expected to focus on the nuances of specific novel aspects of a complex decision instead of reporting in detail on the whole process. However, we also found a large fraction of applied examples with low numbers of critical decision elements. This indicates that insights from decision-science have not yet become standard in decisions that inform conservation practice, or at least are not reported in the published documents that describe practices. There is a range of potential scenarios in which the use of all elements may not be necessary or possible. For example, we could not assess if conservation scientists used key elements but did not adequately describe the details or simply failed to present them. One reason for not using some elements is the inherent trade-off between resources spent at planning, including decision-making, and resources spent on action (Buxton et al., 2020). In many cases, conservation actions are opportunistic (Meir et al., 2004; Pressey & Bottrill, 2008), and decisions have to be made quickly, or budget and expertise do not allow for a detailed decision-making phase. For example, the deliberation on trade-offs between multiple objectives can easily become complex and time-consuming. Involving stakeholders to scope out additional objectives and discuss trade-offs requires time, resources, and additional skills of facilitation and maneuvering group dynamics, which adds to the complexity of a more narrowly framed problem context. Scoping and running additional ensembles and sensitivity analyses is similarly time and resource consuming. Although these reasons are compelling arguments for the necessary balance between feasibility and rigor, we believe it is most important to acknowledge the importance of key elements during decision-making and to be transparent on the reasons when omitting them. That way, the conservation community would facilitate understanding and best practice, and make it easier to evaluate successes and failures.

4.6 | Representativeness of results

It could be questioned if the 466 examples that we identified in this review are representative of the comprehensive literature on academic and applied decisions on conservation management actions. There are likely many published examples of decision processes that do not include the phrase "decision-making" in the main text, and only a small fraction of existing gray literature is synthesized into peer-reviewed publications. However, the identification of 128 conservation practice examples in a sample drawn from a database of peer-reviewed literature was much higher than we expected when considering the often cited and controversially discussed "implementation gap" (Sunderland et al., 2009). Additionally, the use of key decision support elements was more strongly related to the use of specific frameworks than to the context of applied conservation practice versus academia. Hence, we believe our sample to be representative of the broad range of contexts, including genuine applications.

The number of identified publications that utilize MCDA is similar to a recent review (Adem Esmail &

Geneletti, 2018). In contrast to Esmail et al., we did not find a strong dominance of locations in Europe, with similar numbers of examples in the United States. This difference might stem from our focus on management actions for biodiversity conservation, which excluded a larger number of site-selection studies for industrial purposes. Another difference is the higher rate of sensitivity or uncertainty analysis, with 80% of examples in our review including some sort of sensitivity or uncertainty analysis, while Esmail et al. reported rates under 60%. A dominance of academic examples for SCP is supported by earlier assessments (Knight et al., 2008; Kullberg & Moilanen, 2014), but also contrasted by a recent survey that found similar numbers of examples, but where most were intended for implementation (Sinclair et al., 2018). Overall, we felt that the total numbers of papers and different frameworks can, compared to these other studies, be considered as a representative sample.

Classifying text is not a trivial task, as a different judgment on the same issues is common among experts (Kahneman et al., 2021). Even though we developed and tested instructions for choosing categories during the coding phase, making a judgment on the use of a specific element based on descriptive text is difficult. For example, one publication (Koehn & Todd, 2012) focused on the importance of trade-offs, and described it with theoretical examples, but did not use it for a final decision. A second paper (Chadés et al., 2015) mentioned trade-offs only briefly, but presented a figure that showed that they based their choice of action on information from a trade-off analysis in the form of a cost–benefit curve. To avoid difficult subjective judgments, such as coding the inclusion of trade-offs based on the judgment if it has been described in "enough" detail, we decided to code a trade-off only as present when it was clearly used to inform the final choice of management strategy. This is a clearer condition, as it did not need subjective judgment on how much description is enough and where to draw the line when trade-offs were described (sometimes in great detail) but were not used. We acknowledge that we were only able to classify what was described in the text. In many cases, key elements might have played a role in the decision but were not described in the publication and could therefore not be coded. Published documents about decisions that do not describe all key elements that were used are unfortunately not very useful to inform readers on how the decision was made and how rigorous the process was, despite the text's potential usefulness for other matters. Our results suggest that it is common practice among conservation scientists and practitioners to omit key decision elements frequently in their decision-making processes, or to at least not include them in descriptions of these processes. If this is true, the scientific literature is not a good place to look for fundamental guidance for decision-making processes but can only provide additional inspiration when it comes to novel approaches or specific details in the decision process.

4.7 | Conclusion

If conservation scientists and practitioners want their publications to improve and inform management strategies, decision processes should be based on insights from decision-science, and the use of key decision elements should be reported more transparently and comprehensively. The intent of our study is to encourage the conservation community to embrace the discussion and use of these five elements of robust decision-making, and to report transparently about factors that hinder their inclusion in decision-processes. Academic studies need to increase the focus on decision-making strategies and management types that are common in applied contexts. Some specific circumstances do not allow the inclusion of all elements due to lack of data, time constraints, or other means, but decision-makers need to be aware of the increased risks that they invite through a less rigorous decision-making process. While outcomes of conservation actions are most often uncertain due to the inherent complexity of natural systems and their inherent uncertainties, the process of decision-making can be used to judge the quality of the decisions being made (Hammond et al., 1998; Riley & Gregory, 2012). Such a process leads to the creation of feasible and realistic strategies for the implementation of management actions on the ground. Time and budgets are limiting existing efforts to protect our fast-disappearing natural heritage on this planet. Robust decision processes should be a high priority when people make choices about the course of action that is most promising to change the ongoing trend of loss of biodiversity. Finally, in order to understand and learn from the current state and trajectory of applied conservation management on a global level, there is a need to translate existing descriptions of conservation decisions from other languages into the English-speaking literature. We recommend that decision-makers seek detailed instructions beyond publications in the field of conservation to be able to employ rigorous practice during the decision-making process when planning for the conservation of biodiversity.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

All data and code are made available on figshare (https://doi.org/10.6084/m9.figshare.17205713.v1).

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SUPPORTING INFORMATION

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

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