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REVIEW

Decision Support Frameworks and Tools for Conservation

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Abstract

The practice of conservation occurs within complex socioecological systems fraught with challenges that require transparent, defensible, and often socially engaged project planning and management. Planning and decision support frameworks are designed to help conservation practitioners increase planning rigor, project accountability, stakeholder participation, transparency in decisions, and learning. We describe and contrast five common frameworks within the context of six fundamental questions (why, who, what, where, when, how) at each of three planning stages of adaptive management (project scoping, operational planning, learning). We demonstrate that decision support frameworks provide varied and extensive tools for conservation planning and management. However, using any framework in isolation risks diminishing potential benefits since no one framework covers the full spectrum of potential conservation planning and decision challenges. We describe two case studies that have effectively deployed tools from across conservation frameworks to improve conservation actions and outcomes. Attention to the critical questions for conservation project planning should allow practitioners to operate within any framework and adapt tools to suit their specific management context. We call on conservation researchers and practitioners to regularly use decision support tools as standard practice for framing both practice and research.

Introduction

The practice of conservation increasingly takes place in complex, uncertain, and dynamic socioecological contexts (Folk *et al.* 2005). Given this complexity, there is increasing attention toward methods for doing a better job of linking knowledge to action (e.g., Sunderland *et al.* 2009; Walsh *et al.* 2015). These challenges require increased attention to conservation planning (Groves & Game 2015). The goal of conservation planning is to support actions to achieve explicitly defined objectives through documented, structured, and socially engaged processes (Groves & Game 2015). To identify and select actions that are most likely to achieve objectives, we suggest that planning consists of answering a suite of fundamental questions (who, what, why, where, when, how), within the planning components of adaptive management (project scoping, operational planning, learning). Conservation planning and decision-making frameworks have emerged as an established means to address the need for structured support of conservation actions (e.g., Margules & Pressey 2000; Pullin & Knight 2001; Martin *et al.* 2009; CMP 2013; Cook *et al.* 2014a). Conservation frameworks provide overarching guidance for planning and decision support, but also feature a variety of specific tools with which to accomplish conservation planning.

We define a conservation framework as a cohesive set of tools and guidelines within which one may structure the planning and management of a conservation program or project (e.g., Systematic Conservation Planning; Margules & Pressey 2000). We define tools as a structured set of specific *activities* used to accomplish one or more critical planning steps (e.g., Vulnerability Assessment; Glick *et al.* 2011). As such, we distinguish our use of tools from the array of highly valuable conservation information sources, such as IUCN redlists or geospatial databases that also sometimes referred to as tools (e.g., Mace *et al.* 2008). A number of frameworks now exist that contribute to a varied, if not somewhat confusing, suite of toolkits for conservation practitioners. We seek to help structure and clarify thinking about conservation tools, frameworks, and their potential utility toward deploying effective conservation actions by linking tools to fundamental questions within the planning steps of adaptive management. We focus on tools that have been developed within five prominent conservation planning and decision-making frameworks.

Our purpose is threefold. First, we seek to provide conceptual guidance to practitioners who are confronted by a seemingly endless array of new and nuanced frameworks that claim to improve conservation practices. Further, deploying tools in support of conservation is costly and no effort can deploy all the available tools; tool selection is an important decision. Although this guidance points to specific tools, our approach is to focus on structuring how to think about a conservation challenge in order to find effective solutions. Second our synthetic focus on choosing tools for the question at hand seeks to reduce the apparent current tension around choosing "the right" framework for a conservation project. Third, we identify gaps in the conservation toolkit and suggest directions for conservation scientists seeking to augment the existing toolkit for conservation. Through this, we call on conservation scientists to revisit the need for coordinated efforts to establish broadly accepted standards of conservation practice.

Five decision support frameworks

Advances in conservation planning and decision support have been driven by a suite of frameworks that have become generally recognizable and broadly used. We examine five decision support frameworks selected because of their general conservation utility and their deployment by multiple resource management agencies and/or nongovernmental conservation organizations (Table 1). Our focal frameworks are: (1) Strategic Foresight (SF) (Cook *et al.* 2014a), (2) Systematic Conservation Planning (SCP) (Margules & Pressey 2000; Sarkar *et al.* 2006), (3) Structured Decision Making (SDM) (Martin *et al.* 2009; Gregory *et al.* 2012), (4) Open Standards for the Practice of Conservation (OS) (CMP 2013), and (5) Evidence-Based Practice (EBP) (Sutherland 2000; Pullin & Knight 2001; Sutherland *et al.* 2004).

Strategic Foresight emphasizes planning actions given uncertain future conditions of the social and natural world (Cook *et al.* 2014a). SF provides a structured process to assess a range of plausible future conditions and identify actions most likely to achieve a desired future state (Coreau *et al.* 2009; Cook *et al.* 2014a,b). SF can address the fundamental questions of conservation relating to the uncertainties associated with forecasting future states (e.g., what actions are most likely to succeed across different future scenarios). Tools in SF tend to focus on helping stakeholders target critical future uncertainties in management choices.

Systematic Conservation Planning seeks to optimize where to deploy conservation actions, on which targets, and how best to protect diversity (e.g., protecting habitats, implementing weed management) (Margules & Pressey 2000; Sarkar *et al.* 2006; Groves *et al.* 2012). SCP seeks cost-efficient solutions, each consisting of a portfolio of areas, that achieve multiple, quantitative objectives in the face of practical constraints (Margules & Pressey 2000; Sarkar *et al.* 2006). Tools associated with SCP include identifying and prioritizing where to take action, minimizing cost (e.g., dollars, forgone opportunities) while achieving conservation, or other, objectives (Sarkar *et al.* 2006).

Structured Decision Making seeks to identify optimal actions to achieve desired outcomes while balancing diverse stakeholder objectives, often in the face of uncertainty (Runge *et al.* 2011a, Gregory *et al.* 2012). SDM seeks quantitative, explicit assessment of the consequences and trade-offs of choosing amongst a set of alternative actions. Tools deployed through SDM range across a wide array of approaches that are designed to facilitate making choices among actions that differentially achieve a set of potentially competing objectives (Gregory *et al.* 2012).

The Open Standards for the Practice of Conservation combine principles of project and adaptive management to design actions explicitly linked to expected outcomes and to define measures enabling the assessment of progress toward measurable objectives (CMP 2013). The OS provide processes for developing a conceptual model of the interacting threats and contributing factors that frame the conservation situation, identifying both priority actions and the critical results necessary to assess whether actions lead to desired outcomes. Rooted in project management, OS has tools for many of the foundational questions, but also that focus on tracking and accountability.

Table 1 Five critical decision support frameworks in common practice by globally distributed government and nongovernmental practitioners. Each framework is linked to its conceptual foundation and its core focal question. Example applications, core tools, key references, and evidence of their use in conservation are also described

	Theoretical foundation	Focal problem	Example applications	Core tools	Key references	Evidence of use; key users, synonyms
Strategic Foresight	Futures research	What are the critical future possibilities and uncertainties?	Climate adaptation planning; restoration; identifying emerging threats and opportunities	Horizon scanning; scenario planning; vulnerability assessment; backcasting	Cook (2014a,b); Coreau 2009; Glick 2011	U.S. National Park Service; U.K. government Foresight group; National Fish and Wildlife Federation's Climate Smart Adaptation; DEFRA (U.K.); Australian Department of the Environment
Systematic Conservation Planning	Geospatial planning	Where are the critical locations for action?	Reserve design; reserve acquisition; off-park management	Spatial prioritization tools	Margules & Pressey (2000); Sarkar *et al.* (2006)	>600 peer reviewed articles; numerous high-profile case studies
Structured Decision Making	Decision theory	What actions are likely to most efficiently achieve competing objectives?	Choosing amongst specific alternative action plans	Multicriteria assessment; consequences tables; expert elicitation; value of Information	Gregory *et al.* 2012	Focus of 10+ short courses/year at the National Conservation Training Center (U.S.); hundreds of applications by federal and state agencies in the United States, Canada, and Australia
Open Standards for the Practice of Conservation	Adaptive project management	How can we best use our limited time and funding to achieve desired outcomes and learn from our work?	Reserve management; bioregional conservation planning; assessment of market-based conservation strategies	Situation analysis; viability analysis; threat prioritization; results chains; intermediate objectives; effectiveness indicators; work planning; common lexicons	CMP (2013); Salafsky *et al.* (2008); cmp-openstandards.org miradi.org miradishare.org	Over 10,000 Miradi software users; thousands of projects; broad adoption by NGOs, government agencies, and funders around the world
Evidence-Based Practice	Evidence-based medicine	How effective are our actions (including context)?	Evaluating the effect of specific conservation actions and the extent to which they vary and why	Evidence synthesis; systematic reviews; maps; evidence synopses; evidence repositories	Pullin & Knight (2001); Sutherland *et al.* (2004); conservationevidence.com environmentalevidence.org	Government agencies (e.g., Defra and Natural England, U.K., Swedish EPA); NGOs (e.g., RSPB, CIFOR, Vincent Wildlife Trust); intergovernmental bodies (e.g., GEF).

Evidence-Based Practice seeks to synthesize and disseminate evidence on the effectiveness of management interventions (Sutherland 2000; Pullin & Knight 2001; Sutherland *et al.* 2004). The products of evidence synthesis tools, such as systematic reviews (Pullin & Knight 2001) and evidence synopses (Dicks *et al.* 2014), can provide support for rapid selection of the most effective management actions for the decision context. Tools associated with EBP tend to facilitate synthesis of existing knowledge and assist in determining where past actions/interventions may be most applicable.

Common framework attributes

Our focal conservation frameworks share common principles of establishing clear objectives, identifying critical uncertainties, and creating a documented planning process that integrates knowledge into decision support. Changing conditions, knowledge, and technologies, along with the likelihood of imperfect outcomes, call for decisions to be revisited, making each framework iterative (some explicitly, others implicitly). Another common theme among frameworks is that they embrace flexibility. Each provides a diversity of tools based on problem needs, but practitioners using these frameworks have promoted the value of mixing and matching tools from other frameworks based on the peculiarities of the conservation challenge and the relevant project stage (e.g., planning, action or learning) (Table 2). For example, Bryan *et al.* (2011) integrated scenario planning (SF) as a tool into systematic conservation planning in the Lower Murray River Basin (Australia), while Schofield *et al.* (2013) applied an evidence-based approach to learning within a systematic conservation planning context for a marine protected area in Greece. This transferability of tools is useful to consider for scientists when developing new approaches to problem solving and to practitioners when seeking tools that are fit for purpose.

Evidence of the perceived value of using decision support frameworks in conservation practice abounds (Table 1). We find this evidence in the investment by conservation NGOs in developing and training in frameworks, such as the OS (Redford *et al.* 2015). Likewise, government agencies are increasingly using these decision frameworks (Runge *et al.* 2011a; Pressey *et al.* 2013). For example, many U.S. Federal and State Fish and Wildlife agencies are using the OS in their planning work (AFWA 2012; USFWS 2014), the National Conservation Training Center offers training in SDM to hundreds of practitioners each year (Johnson *et al.* 2015), and centers for EBP are emerging globally (Pullin & Knight 2013).

Fundamental process questions of conservation

Conservation practice requires answering a series of familiar and fundamental questions: *why* should society seek to conserve some part of nature and what are the specific objectives for management; *who* has a stake in and responsibility for decisions related to a conservation project; *what* actions are most likely to achieve stated objectives; *where* should conservation actions occur; *when* do we need to take action; and *how* will we know if the action achieves intended objectives? These are foundational questions that can be reframed in different ways in different contexts, but serve to outline fundamental issues that conservation projects address through planning and decision support (Table 3).

Within an adaptive approach to conservation planning and project management these fundamental questions must be revisited several times: to guide overarching planning (*project scoping*), specific action planning (*operational planning*), and structuring information acquisition and assessment to foster learning (*learning*) (Table 3). Although action is the primary concern of conservation, it is not our focus here. Actions are varied, project-specific and involve myriad specific implementations. Our focus is on supporting decisions to take actions through deliberative planning processes.

Through project scoping, answering fundamental questions frame the larger context for management decisions, such as establishing goals and including stakeholders (Table 3). In operational planning, questions focus on explicit objectives and the supporting decisions for specific actions, such as why we think one set of actions is better than another (Table 3). The learning phase focuses on questions that help us understand the impact and effectiveness of the actions that were taken and how we can adapt to improve practice (Table 3).

Each of our focal frameworks addresses at least some of these fundamental questions and provides a suite of tools to assist decision makers to find the answers. However, we recognize that conservation problems span a dizzying array of specific and dynamic contexts. Others have tried to specify a roadmap for adaptive management to help guide this often nonlinear process (e.g., Groves & Game 2015). We acknowledge and recognize that conservation challenges within complex socioecological contexts require a nonlinear process that often requires working simultaneously on various steps of adaptive management, as well as iteratively revisit-

Table 2 A list of key tools applied within focal conservation decision support frameworks featured herein. For each tool we list a principally identified use

Tool	Use
Strategic Foresight	
Scenario planning	Assess the likely outcomes of strategies deployed in any of several alternative plausible future physical, ecological, or social states (e.g., likely spread of a noxious weed with or without control efforts, with and without climate change).
Vulnerability assessment	Assess the relative vulnerability of a suite of potential conservation target features (e.g., species, ecosystems) relative to one or more stressors based on the exposure of targets to the stress, the sensitivity of the target to the stress, and the likely adaptive capacity of the target to the stress.
Horizon scanning	Aggregating information from a wide variety of sources to inform a problem, often used to identify issues that could become important but are currently poorly recognized.
Backcasting	A process for linking future preferred states, and needs required to achieve those, to our understanding of processes that generated the current state.
Systematic Conservation Planning	
Vulnerability assessment	As above.
Data on targets	Compile data on conservation targets, reflecting the goals of the exercise, and their locations, extent, abundance, or probability of occurrence in each of the planning units (units of assessment and comparison).
Explicit objectives	Interpret the broad goals of the planning exercise into quantitative objectives (e.g., with MARXAN) or benefit functions with increasing investment (e.g., Zonation), based on targets' distributions, exposure to threats, life-history requirements, and other considerations. In some cases, set objectives for social and economic benefits.
Cost assessment	Develop spatial data on the costs of conservation action, ideally including acquisition, opportunity, management, transaction, and damage costs.
Spatial planning tools	Find cost-efficient solutions, consisting of planning units and, in most cases, already-existing conservation areas, to achieve all conservation objectives (e.g., species in reserves) or to maximize the achievement of objectives subject to a ceiling on costs.
Structured Decision Making	
Consequences table	A tool used to evaluate the trade-offs among particular actions or action sets based on their estimated performance to achieve the suite of critical project objectives. These objectives should include human values (e.g., the cost of implementation).
Multicriteria assessment	The formal evaluation of alternatives assessed using a range of criteria weighted to be placed on a common scale of value.
Expert elicitation	The use of experts in a formal structured manner to assess both knowledge and certainty about that knowledge.
Value of information	Quantitative evaluation of the effect of resolving uncertainty on the achievement of management objectives.
Bayesian updating	Formal quantitative methods for updating the belief in alternative hypotheses based on new information received.
Adaptive optimization	Solution algorithms for identifying management strategies that solve the "dual-control problem" by acknowledging the value of reducing uncertainty to effective choice of future management actions.
Open Standards	
Situation analysis, viability analysis, threat prioritization	Identify conservation and human wellbeing targets and develop a graphical conceptual model that shows the major direct threats facing these targets as well as contributing factors that are drivers of these threats. As part of this situation analysis, assess key ecological attributes that determine the viability of conservation targets and prioritize threats that require action in terms of the scope, severity, and irreversibility of their impacts on targets. The situation analysis can also be used to brainstorm and then prioritize actions at key strategic intervention points.
Results chains, intermediate objectives, effectiveness indicators	The conceptual model is redrawn to explicitly create a series of if–then hypothesis statements about the impacts of a conservation action (e.g., if fishing is better regulated by government officials, then illegal shark fishing will decrease). These results chains are used to establish the plausibility of an action achieving desired outcomes and to develop intermediate objectives and effectiveness indicators that can be used to learn whether actions are working as intended.
Work planning	Actions and component tasks are costed out and assigned to project team members. This enables determinations of cost-effectiveness.
Common lexicons	Standard terms to describe conservation threats and actions as well as standard results chains that form the basis for systematic learning across projects and organizations.
Evidence-Based Practice	
Evidence synthesis	The collation and synthesis of available evidence in an explicit, repeatable, and transparent manner. Systematic reviews and Systematic mapping are specific examples of Evidence synthesis.
Systematic review	The collation, synthesis, and critical assessment of available evidence in an explicit repeatable transparent manner in relation to a specific question, sometimes including meta-analysis.
Systematic (evidence) mapping	A systematic collation and configuration of the available evidence on a (often broad) topic completed following an explicit, repeatable and transparent protocol.

Table 3 A proposed list of fundamental questions that are addressed within project scoping, operational planning, and learning stages of conservation project management

	Project scoping	Operational planning	Learning
Why	Why should society care about this problem?	Why are these the right actions and why do we think that they will achieve the goals?	Why do we think that actions succeeded or failed?
Who	Who are the relevant stakeholders?	Who is responsible for implementation, monitoring, and information synthesis?	Who took action and did actions reflect stakeholder goals?
What	• What are the key stakeholder goals? • What are the trade-offs among goals? • What are the management targets that best reflect goals? • What are current states of targets? • What are primary threats to targets? • What are key drivers of primary threats? • What are critical intervention points? • What are critical uncertainties?	• What are the intermediate or proximate objectives? • What are the best actions to take? • What is the evidence that these actions will be the most effective? • What are the trade-offs for taking one set of actions over another? • What are the action thresholds or triggers?	• What evidence will address action success? • What actions were taken? • What actions should be monitored? • What monitoring was done? • What evidence do we have that actions led to desired outcomes? • What evidence leads to a conclusion that actions failed? • What evidence suggests a need to revisit goals?
Where	Where is the spatial extent of the project?	Where should actions and monitoring be implemented?	What is the evidence that actions were deployed in the right places?
When	When do thresholds trigger actions to be prioritized?	When should actions and monitoring be deployed?	When did actions occur and was this in response to the appropriate priorities and triggers?
How	How do we create pathways for or barriers to success?	How do we measure progress towards objectives and the effectiveness of our actions?	How do we capture lessons so that others can learn from this project?

ing steps and stages as conditions and decision contexts change.

Tools for conservation practice

Each of the five frameworks described above is implemented through a suite of tools, a selection of which is described in Table 2. These tools are designed to support project scoping, operational planning, and learning. Deploying tools requires information, and this provides an opportunity for research to inform practice. Framing conservation research around conservation practice may increase the likelihood of its utility and improve the practice of conservation. However, framing research this way requires viewing the research problem from the context of the practitioner's need for information and the context in which that information will be used. Increasingly, researchers are recognizing the value of their closer links to practitioners (e.g., Cash *et al.* 2003; Cook *et al.* 2013; Beier *et al.* 2017; Bower *et al*, 2017).

Collectively the emerging tools of conservation planning and management represent a diverse and flexible toolkit that can address problems within any natural resource management decision context (Table 2). Choosing the right tool for a specific challenge requires understanding the potential suite of available tools, which fundamental question they are designed to address, and how they can help practitioners resolve particular challenges within the planning cycle (Table 4). Embedding tools within a framework allows practitioners to systematically address fundamental conservation questions within the contexts of project scoping, operational planning, and learning.

Gaps and complexities in planning tools

Despite this broad suite of tools, there remain important steps in conservation planning with little specific guidance. One of these areas of potential tool development is in stakeholder identification, and engagement ("Who"; Table 4). All frameworks explicitly recognize the importance of establishing a functional stakeholder group. Just how to identify the right stakeholders for a project, or how to define the decision authority of stakeholders are areas of much recent deliberation. An ISI search

Table 4 Examples of how tools can help to answer one or more of six fundamental questions within the three critical planning phases of adaptive management described in this article. Tools are linked, wherever possible, to focal frameworks or a key citation. Linking to a citation indicates a tool that has been developed outside the specific context of these focal frameworks. Italicized generic terms (e.g., project monitoring) refer to practices often engaged in, but lacking specific call-out tools. Underlined items are areas of potential new tool development

	Project scoping	Operational planning	Learning
Why	Setting objectives (FS,SDM,OS,SCP); expert elicitation (SDM); social science research	Multicriteria assessment (SDM); threat prioritization (OS)	Bayesian updating (SDM)
Who	Stakeholder influence mapping (Sova *et al.* 2015); stakeholder analysis (Reed *et al.* 2009)	Work planning (OS)	Work plan evaluation (OS); *project monitoring*
What	Situation analysis (OS); vulnerability assessment (SF); scenario planning (SF); threats assessment (OS); data on targets (SCP)	Consequences tables (SDM); results chains (OS); evidence synthesis (EBM); adaptive optimization (SDM)	Impact evaluation; effectiveness evaluation
Where	Spatial planning tools (e.g., MARXAN, ZONATION) (SCP)	Spatial planning tools (e.g., MARXAN, ZONATION) (SCP)	*Project monitoring tools*
When	Scenario planning (SF); vulnerability assessment (SF)	Decision triggers (Cook *et al.* 2016)	*Project monitoring tools*
How	Expert elicitation (SDM); cost assessment (SCP);	Backcasting (SF); evidence syntheses (EBP); systematic review (EBP); systematic mapping (EBP)	Value of Information (SDM); Bayesian updating (SDM)

(March 14, 2017; search terms "stakeholder and "conservation" or "natural resource management") returned 1,664 papers, 1,197 (72%) of which were published in 2010 or later. Our focal frameworks do not identify specific tools for stakeholder identification, although most recognize that choosing stakeholders depends on who is funding a project, making decisions, and living with outcomes (CMP 2013). The care needed in choosing stakeholders increases with the degree of conflict or divergence in values and objectives among groups that control decisions envisioned by the planning team. Stakeholder influence mapping (Sova *et al.* 2015) and stakeholder analysis (Reed *et al.* 2009) begin to form structure for developing robust stakeholder groups.

Identifying threats has been a primary preoccupation of conservation research (Fazey *et al.* 2005). Considering threats within a planning context ("What"; Table 4) is likely to shift focus away from assessments of isolated threats toward evaluating the relative cost of an integrated suite of threats (e.g., threat syndromes; Burgman *et al.* 2007). Practitioners are nearly always forced to consider a suite of threats, possibly relating to competing objectives, and to understand threats within the context of social acceptability of specific actions (Gregory *et al.* 2012). Thus, for researchers to contribute to improving the understanding of conservation threats, it would be far more helpful to consider integrated threats assessments than to offer an assessment of a particular kind of threat to an individual species. Integrated threats assessments, however, are difficult to conduct within a research context.

A subtle, but critical, point of distinction between the tools offered by various frameworks centers around certainty that an action will result in a particular outcome. Two frameworks (SDM and SCP) place a large emphasis on quantitative assessments to optimize what or where actions should be taken. Within this emphasis there is sometimes a presumption that an action will result in an intended outcome. SDM encompasses several branches of decision theory that focus on making decisions in the face of uncertainty (risk analysis, Burgman 2005; info-gap decision theory, Ben-Haim 2006) and addressing uncertainty is built into most optimization processes (e.g., Runge *et al.* 2011a). But multiobjective criteria assessment, consequences tables and spatial planning tools work best when there is a reasonable certainty that an outcome will be achieved through an action (e.g., protecting a parcel will protect a species found in that parcel). This is in fact, often a defensible position.

In contrast, three frameworks (SF, OS, EBP) begin with the presumption that we do not know if an action will result in an outcome. Thus, SF uses scenario planning, vulnerability assessment, or backcasting to estimate the likelihood that some action will result in a desired outcome (Table 2). The OS focus on situation analyses and results chains as explicit hypotheses of cause and effect so that actions can be evaluated against outcomes to determine if objectives are being achieved (Table 2). Finally, EBM tools focus on aggregating information in order to build a case around estimating whether an action will, or will not result in intended outcomes.

These subtle but important distinctions need consideration for two reasons. First, they imply that SDM and SCP tools may partner well with SF, OS and EBM tools in specifying action-to-outcome hypotheses, testing them through action, and optimizing action selections based on numeric models. Second, it is important to recognize these differences because of the challenge of implicit bias and the potential for experts to overestimate confidence in knowledge of complex systems (Gregory *et al.* 2012).

Capturing learning, analyzing information, and sharing information is critical for improving conservation practice (Pullin & Knight 2009). Conservation practitioners increasingly understand that adaptation of initial plans is inevitable, given limitations of data and models about biodiversity and socioeconomic variables relevant to implementation on the ground (Pressey *et al.* 2013). Yet, figuring out what actions are effective is rarely a focus of conservation research. A review of what conservation scientists published (Fazey *et al.* 2005) found that 40% of the conservation literature documented threats to biodiversity, while only 13% tested potential conservation interventions. This problem is hardly unique to conservation. Evidence-based approaches have emerged in many fields as a means to better assess what works and what does not (Sutherland *et al.* 2004).

Learning is important at two scales: within an individual project and among projects to inform broader conservation practice. Two frameworks, OS and SDM, explicitly include tools to foster learning at the project scale (Table 2). OS identifies steps to plan monitoring of critical information, collect data and compare outcomes to specific, measurable, achievable, relevant, and time-specific (SMART) objectives (Maxwell *et al.* 2015), in order to assess progress and to learn. Unfortunately, reviews of impact monitoring, assessment, and learning suggest that this is functionally a weak point of conservation practice (Redford *et al.* 2015). SDM provides quantitative tools for evaluating the value to a decision maker of acquiring more information before acting (Runge *et al.* 2011b). EBM is specifically designed to aggregate and assess information so as to learn which actions work on what problems and what does not (Sutherland *et al.* 2004). Clearly identifying and distinguishing these forms of learning is critical in choosing the right tool for a particular problem.

Case studies in cross-fertilization

Numerous research papers have described integration of tools from different frameworks to advance research on conservation practice (e.g., Bryan *et al.* 2011; Schofield *et al.* 2013). It is more difficult to find examples of current projects that have made a conscientious effort to deploy tools from multiple frameworks in order to improve conservation practice. We highlight two such cases.

The Puget Sound Partnership (PSP) is a Washington State agency tasked with leading a regional effort to protect and restore the Puget Sound and its terrestrial watersheds, an ecosystem that spans 30,000 km^2 and contains nearly 5 million people. The PSP convenes hundreds of partner organizations to identify priorities, advance a common agenda, and strategically invest in actions with the highest likelihood of gains in mission success. The PSP initially engaged in convening partners to create a common framework to identify priorities within nine local subareas of the Puget Sound, called Local Integrating Organizations (LIO's). Each LIO developed a situation analysis (OS), threats/pressure assessment (OS) to identify recovery targets (http://www.psp.wa.gov/science-open-standards.php). The PSP also uses SDM tools to create a Vital Signs assessment and provide objectives ratings for their action agenda (http://www.psp.wa.gov/science-based-decision-making.php), while the LIO's use consequences tables (SDM) in their annual work plans to evaluate trade-offs in achieving objectives among actions. Together, integrating OS and SDM tools has been a powerful combination for integrating actions and reporting achievements and challenges to the public.

The Daly River Catchment is one of three catchments to coast projects in northern Australia (http://conservationplanning.org/research/catchment-to-coast-planning/), and is earmarked for further agricultural development due to its arable soils and reliable water supply. To understand possible future states of the catchment and the impacts of expanded agriculture on diverse local and regional stakeholders, researchers have used a combination of scenario planning (SF), spatial planning tools (SCP) and a variety of SDM tools (e.g., expert elicitation, multiobjective evaluation criteria) to shape choices for local groups engaged in resource management in this 52,000 km^2 region (Alvarez-Romero *et al.* 2015). These efforts culminated in a Daly River Management Advisory Committee plan (http://www.nespnorthern.edu.au/wp-content/uploads/2015/11/1.1_fact_sheet_web.pdf). Government funding for the committee's planning and implementation work was terminated in 2013, although the integrated planning studies remain relevant to decisions by government, natural resource management groups, and conservation NGOs (Adams *et al.* 2016).

Improving the practice of conservation

Our review of the primary tools of five decision support frameworks leads to three conclusions. First, prioritizing fundamental conservation questions within adaptive management planning stages can help sharpen the focus for picking the right tool for the right problem. Focusing on tool selection, we argue, will foster broader cross-framework deployment of tools and improve conservation practice. It has been our collective experience that there is a tendency for conservation scientists to cling a little too tightly to the framework that each knows the best. Breadth is a strength, and we need to leverage that strength for successful practice. Each of our focal frameworks approaches conservation practice from a unique angle, bringing specific strengths to particular kinds of challenges. However, each framework is also flexible and can be amended to use tools for a variety of purposes and from a variety of sources, including merging with other frameworks. While it may be too much to expect practitioners to become and remain conversant in all frameworks, guidance for where and when particular tools have been deployed successfully will help practitioners broaden their toolkits and identify the most appropriate tools for their context. Just as science is strengthened by an approach that focuses on answering questions, adaptive management for conservation is strengthened by planning and decision support that identifies and answers questions critical to achieving desired outcomes.

Second, gaps in tool coverage point to potential fruitful research to develop and hone tools for conservation. Although there are tools for many questions at most stages, tools for particular questions at particular planning stages remain less developed (Table 4). Tools to guide planning and action are diverse and nuanced to reflect the diversity of challenges that arise around the specifics of actions. Within this context, some tools have garnered a large fraction of the interest among researchers. Deploying spatial planning tools, or multicriteria assessments is a frequent focus of conservation research. In both cases, a large number of papers have been published on these topics since 2010 (at least 860 for spatial planning tools; 159 for multicriteria assessments) (ISI Web of Science search of "conservation" or "natural resource management" and first "Marxan" or "Zonation" or "spatial planning," then "decision" and "multicriteria"; 20 June 2017). In contrast, tools to gauge public support for a project (why conserve some target?) or harness civic engagement are often less quantitative, and less frequently researched. It may be that social processes are more fruitfully guided by principles and good practices, rather than tools, models, and quantification. If so, then integration of best practices for these processes into frameworks, similarly, seems to require further development.

Awareness of how decision support tools are being deployed can also help researchers frame questions to engage more readily in ongoing resource management decisions. Numerous researchers have observed that research often fails to inform practice as intended (Knight *et al.* 2008; Sunderland *et al.* 2009; Matzek *et al.* 2014) and describe the benefits of a more engaged approach to research (Arlettaz *et al.* 2010; Beier *et al.* 2017; Cook *et al.* 2013; McKinley *et al.* 2013; Muller & Opgenoorth 2014). Increasing the understanding of conservation practice by researchers can help break down barriers between knowledge and implementation (Sunderland *et al.* 2009). Surveys that describe research priorities identified by practitioners (e.g., Braunisch *et al.* 2012; Habel *et al.* 2013) is a positive step. Likewise, structured partnerships between practitioners and scientists (e.g., through boundary organizations) (Guston 2001) also serve as a venue for refining research questions for specific practitioner needs (Cook *et al.* 2013; Opdam *et al.* 2013). Increasing awareness of conservation planning tools for decision support among the research community is likely to help researchers better frame their questions for utility in practice.

Conducting management-relevant conservation research requires a clear vision of the conservation context as well as an operational plan for action and learning. Natural resource management decisions are increasingly complex and contested (Schmolke *et al.* 2010; Larson *et al.* 2013). Practitioners often make management decisions about clearly defined threats (e.g., habitat loss), but do so in a world where multiple objectives compete for limited conservation resources, social resistance to particular solutions may preclude their implementation, and our understanding of action outcomes carries high uncertainty. The consequence is that research focused on a single threat, in the absence of the broader context, may go unheeded. The tendency in research is to reduce complexity in favor of answering questions with as much certainty as possible. Although designing studies to address multiple problems is likely to increase uncertainty, careful attention to the decision process will allow researchers to place their hard-earned conservation scholarship within the broader decision context in which the conservation practitioner must operate, thereby increasing its utility.

Finally, we recognize that conservation decision support is a rapidly evolving arena. In 2002 the Conservation Measures Partnership (CMP) formed as a consortium of practitioners from most of the major conservation organizations (Redford *et al.* 2015). The CMP reviewed existing decision support systems in conservation and other fields and used this analysis to develop the common Open Standards framework described in this article. The CMP continues in an effort to update, revise and keep the OS up to date. We think that it is time to renew, and broaden, this sort of effort by asking the science and stewardship leaders of the major conservation NGOs to jointly engage with thought leaders in decision support research to examine what practices have been most effective and where research can help further develop the next generation of tools for effective conservation practice.

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