Toward a shared vision for climate-informed resource stewardship

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Climate-change adaptation planning processes and tools are increasing in number and evolving rapidly. During times of innovation and proliferation, a potential danger is incoherence, when well-intended contributions can overwhelm, create confusion, or mask complementarities. A shared vision is needed to avoid duplication, reduce misunderstandings, and facilitate work across jurisdictions to steward resources undergoing profound changes. Such a vision would document fundamental tools and approaches while allowing flexibility to match highly varied management contexts and organizational missions. Fortunately, the preconditions for coherence exist. Here, we illustrate how climate-change adaptation tools—including scenario planning, conceptual frameworks, structured decision making, and impact-evaluation methods—can be (and are) used in tandem to support adaptation planning that accounts for uncertainty, considers a broad range of strategies and actions, makes transparent and robust choices, evaluates outcomes, and is flexible and responsive to the decision context.

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Climate change will continue to affect natural and cultural resources, infrastructure, and human health and well-being for the foreseeable future (IPCC 2022), requiring planners and decision makers to adapt by preparing for and managing the impacts (Stein *et al.* 2013). Climate-change adaptation science and practice (hereafter, adaptation) is rapidly expanding, with a proliferation of approaches, planning processes, and tools (see Table 1 for operational definitions). Multiple approaches, each with its own process for resource-stewardship planning under climate change, have emerged in recent years (eg Cross *et al.* 2012; Swanston and Janowiak 2012; Stein *et al.* 2014; NPS 2021). Adaptation scientists and practitioners have developed or modified several tools to operationalize these processes, including *climate change vulnerability assessments* (*CCVAs*; Glick *et al.* 2011; Brandt *et al.* 2017), *Climate Change Scenario Planning* (*CCSP*; Miller *et al.* 2022), and conceptual frameworks like *Resistance–Resilience–Transition* (*RRT*; Swanston *et al.* 2016) and *Resist–Accept–Direct* (*RAD*; Schuurman *et al.* 2020, 2022; Lynch *et al.* 2021) (Table 2). However, this radiation of processes and tools has occurred without a consistent understanding of how they relate to one another and are used in adaptation, promoting misperceptions that different tools and processes preclude, rather than enable, coordination and shared learning.

In a nutshell:

- Climate-change adaptation planning tools have proliferated in recent years, as have processes that integrate those tools into planning
- However, with the rapid proliferation of processes and tools has come confusion about how they relate to one another and whether or how they can be used in complementary ways
- We demonstrate the similarities of different adaptation planning approaches, offer a generalized process for climate-informed resource-stewardship planning, and clarify how several tools relate to and enhance the process
- Shared understanding of how these processes and tools relate to one another supports clear communication, efficient coordination, and, ultimately, cross-jurisdictional collaboration in adaptation

Lack of clarity regarding how adaptation tools relate to one another and to broader planning processes is evidenced by calls from researchers and practitioners for new approaches or enhancements that are redundant to existing tools or processes. Such calls have been countered by recent responses; for example, Schuurman *et al.* (2025) clarified that the *RAD* framework was not intended to be a stand-alone planning process but was instead developed for application in extant planning processes together with other tools. Similarly, Reynolds *et al.* (2024) countered critiques of *CCSP* as being

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underdeveloped or insufficiently integrated with resource-management planning processes.

Scholarly exchanges about emerging approaches are natural features of a quickly expanding field. Heterogeneity of planning processes is expected and is perhaps advantageous given varying institutional mandates and needs, and multiple tools are required to put processes into practice. Although currently absent, a common understanding of how these processes and tools relate to one another is important for (1) clear communication among scientists, adaptation practitioners, resource managers, stakeholders, and rightsholders; (2) efficient coordination of further research and development; and, notably, (3) cross-jurisdictional collaboration. Fortunately, existing planning processes and tools exhibit commonalities and complementarities that provide the necessary preconditions for establishing this common understanding.

We seek to move the field of adaptation toward a shared understanding and vision for climate-informed resource stewardship by clarifying the relationships among several leading adaptation planning processes and associated tools for their implementation. First, we display commonalities across existing approaches to demonstrate that most of these follow fundamentally similar processes and synthesize a generalized process for climate-informed resource-stewardship planning. Atop this foundation, we then articulate how specific tools relate to one another and to existing processes.

Table 1. Terms and operational definitions

Term	Definition
Adaptation	"Preparing for and managing change" (Stein *et al.* 2013)
Approach	Application of general and flexible principles toward a particular purpose
Implication	Anticipated positive or negative effect of climate change and related stressors on a resource
Planning process	A systematic and consistent series of steps for developing and implementing a plan
Tool	Specific object or method for deriving or applying information
Vulnerability	Susceptibility to adverse effects as a function of exposure to changing conditions (eg climate), sensitivity to those changes, and (for living resources) capacity or ability to adapt to them (see Glick *et al.* 2011 for details, including definitions of related terms)

A general adaptation planning process

Climate-informed planning is not a simple endeavor, in part because of the uncertainties of projecting future climatic and ecological conditions (Clark-Wolf *et al.* 2025), but also because resource-management planning is not simple. Many types of resource-management plans and planning processes exist, even within a single institution. Different plans and processes also apply at different spatial scales (eg high-level planning for an entire landscape versus detailed planning to restore an individual wetland). Engagement with external partners in complex planning processes is often beneficial, if not required; however, engagement timing and methods are context-dependent (Bamzai-Dodson *et al.* 2021). The range of climate-change impacts, planning policies, management plan types, and partnerships therefore necessitates flexible approaches for adaptation.

Table 2. Prevailing climate-change adaptation tools

Tool	Description
Adaptation menu	Set of previously developed strategies and actions that help practitioners consider a range of options and develop a portfolio or suite of strategies for a given area (Swanston *et al.* 2016)
Climate Change Scenario Planning (CCSP)	Development of a manageable set of divergent, challenging, relevant, and plausible descriptions of how climate may change and affect resources and of a plan to address such effects (Miller *et al.* 2022)
Climate change vulnerability assessment (CCVA)	Evaluation of resource exposure, sensitivity, and (for living resources) adaptive capacity in response to changes in climate (Glick *et al.* 2011; Thurman *et al.* 2020)
Impact evaluation	Understanding the effects of adaptation strategies and how effectiveness may be influenced by site-specific characteristics (Stem *et al.* 2005; Hansen *et al.* 2023); also referred to as "effectiveness evaluation"
Management action	Activities (including cessation of past practice) undertaken to influence the condition of a resource
Resist–Accept–Direct (RAD)	A conceptual framework that defines the general range of adaptation response options, including resisting ecological change, accepting it, or directing it toward new conditions (Schuurman *et al.* 2020, 2022; Lynch *et al.* 2021)
Resistance–Resilience–Transition (RRT)	A conceptual framework that defines the general range of adaptation response options, including resisting ecological change, fostering resilience (enhancing an ecosystem's ability to return to prior conditions following disturbance), or facilitating transition to new ecological conditions (Swanston *et al.* 2016)
Response modeling	Building an understanding of how specific climate drivers affect a resource
Scenario-Based Decision Analysis (SBDA)	Defining resource management problems and solutions while evaluating the influence of potential uncertainties (Miller *et al.* 2023)
Structured Decision Making (SDM)	Framing resource management problems, setting objectives, and analyzing and selecting management strategies (Runge *et al.* 2020)

Several institutions have developed their own approaches to meet the challenges of linking *management actions* with potential climate-change impacts (Stein *et al.* 2013). A side-by-side comparison reveals substantial overlap in the processes that these approaches follow (Figure 1). Distinctions are relatively minor and typically reflect unique features or emphases rather than fundamental differences. Although depicted as linear, such planning processes are typically implemented with cyclical or iterative elements. If decision making is iterated over short timescales (eg seasonal or annual reservoir water releases), monitoring outcomes and updating the understanding of system dynamics can yield incremental improvements in decision making (ie adaptive management). Over longer timescales, as environmental conditions, management authorities, or public sentiments change, managers may re-evaluate the scope of the decision, the specified goals and objectives, and whether strategy alternatives remain appropriate or feasible. This multi-level learning (Pahl-Wostl 2009) can improve decision making, expand choices, and align goals when addressing complex problems.

Tools for implementing the climate-change adaptation planning process

Consistency across adaptation planning processes inspires confidence in the staying power of their common and fundamental features, and in the utility of these features as a foundation for further research and application. To that end, the sections below articulate a generalized adaptation planning process (Figure 2) by explaining what each step entails and highlighting relevant tools. Linking tools to each step is intended to clarify how the constellation of adaptation innovations fits together and where each tool is employed in the process.

Some tools align with multiple steps in this process, accounting for their repeated instances in Figure 2. For example, *Structured Decision Making* (*SDM*) facilitates objective setting (Step 1) and analyzing and selecting strategies (Step 5) (Runge *et al.* 2020). Similarly, *CCSP* identifies consequential uncertainties (Step 2), their implications for resources (Step 3), and management strategies to address key implications (Step 4) (Miller *et al.* 2022). *CCSP* has recently been adapted to incorporate components of *SDM* through a process called *Scenario-Based Decision Analysis* (*SBDA*; Miller *et al.* 2023) (Steps 1–5). Although use of multiple tools may be appropriate in any given step (eg for capturing uncertainty; Clark-Wolf *et al.* 2025), not all tools must be included in a process. Below, we outline each step and align associated tools to show their complementarity and facilitate selection (depending on capacity and desired outputs).

Step 1: define scope, goals, and objectives

In Figure 1, all processes begin with scoping or problem framing, to establish the purpose and focus of the adaptation planning effort and who is involved (including identifying partners and the appropriate timing and method[s] of engagement). Early clarity around planning purpose and scope ensures that the process aligns with user goals and objectives and helps identify appropriate tools to be used in later steps

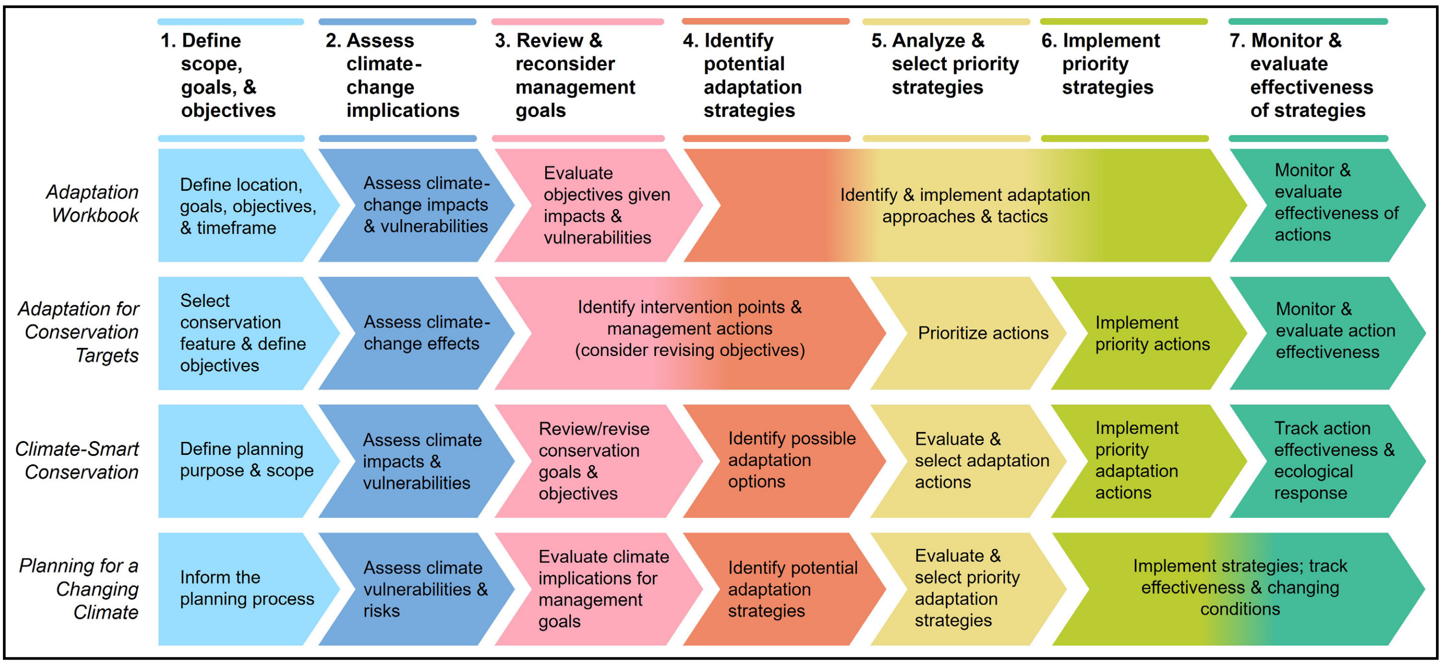

Figure 1. Key stages (top row, from left to right) in four adaptation planning processes: Adaptation Workbook (Swanston and Janowiak 2012; Swanston *et al.* 2016), Adaptation for Conservation Targets (Cross *et al.* 2012), Climate-Smart Conservation (Stein *et al.* 2014), and Planning for a Changing Climate (NPS 2021). Although presented linearly to aid comparison, all are cyclical over sufficient timescales, accommodate return to earlier stages (ie recursiveness) in the process, and may contain more detailed sub-steps.

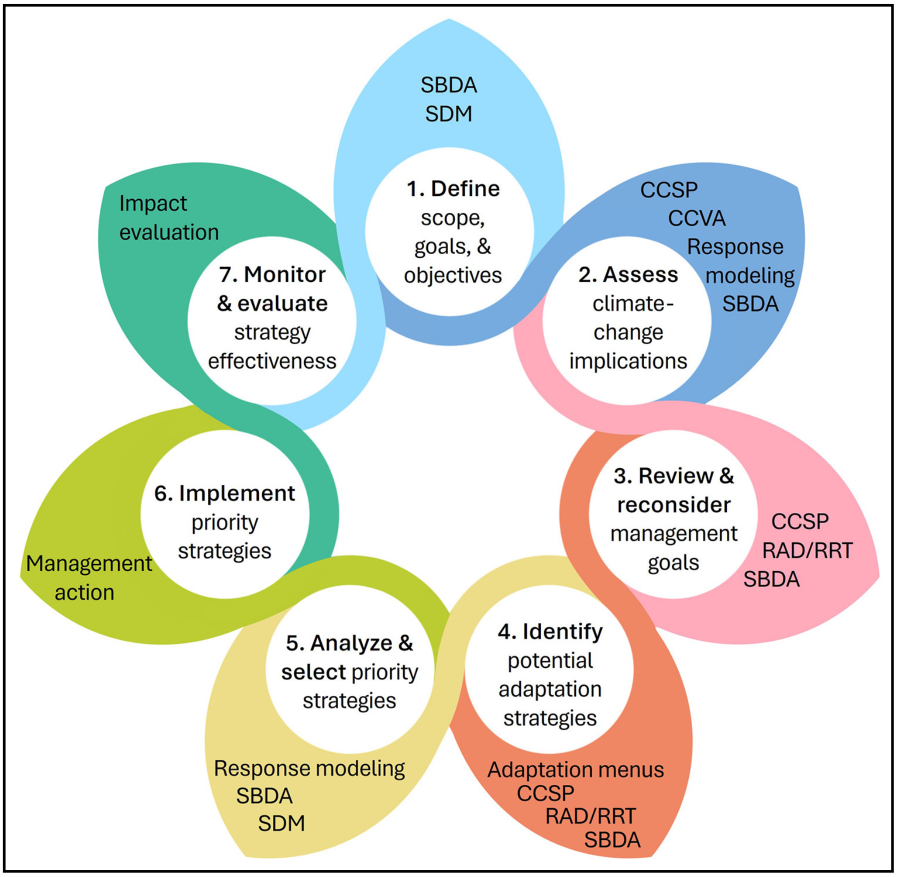

Figure 2. A generalized adaptation planning process depicting the stages at which various tools can be applied. For simplicity, recursive steps are not shown. SBDA = Scenario-Based Decision Analysis; SDM = Structured Decision Making; CCSP = Climate Change Scenario Planning; CCVA = climate change vulnerability assessment; RAD = Resist–Accept–Direct; RRT = Resistance–Resilience–Transformation.

(Stein *et al.* 2014). Framing also helps ensure that scale mismatch does not occur between adaptation actions and the resources or systems being managed (Cumming *et al.* 2006).

Decision making entails evaluating links among proposed actions, expected consequences, and the value placed on those consequences. Thus, selecting an adaptation strategy (set of actions) starts with careful deliberation about those values to establish objectives by which actions and outcomes can be assessed. Setting objectives, and identifying appropriate performance metrics for each, allows any proposed adaptation strategy to be evaluated based on its expected achievements relative to each objective (Hemming *et al.* 2022). Decision-analytic tools, including *SDM* (Runge *et al.* 2020) and the closely related *SBDA* (Miller *et al.* 2023), emphasize thorough objectives-setting and offer a range of theory-based tools and methods for engaging with decision makers, rights-holders, and stakeholders to elicit and refine objectives and their metrics (Hemming *et al.* 2022). Occasionally, goals, objectives, and performance metrics are pre-defined (eg under statutory law); in these cases, the minimum task for this step is to review to confirm that those existing goals and objectives capture all desired elements for the adaptation planning exercise.

Step 2: assess climate-change implications

All adaptation planning processes include a step dedicated to identifying the negative and/or positive implications of climate change for resources of interest. Comprehensive assessments also consider climate-change effects on other related resources and non-climate stressors (eg invasive species). *CCVAs*, *response modeling*, and *CCSP* are commonly used to assess the implications of climate change and related stressors for natural and cultural resources.

CCVAs evaluate the degree to which key resources, ecosystems, infrastructure, and other features may be affected by climate change. Their primary purpose is to assess exposure, sensitivity, and adaptive capacity in response to climate change (Glick *et al.* 2011; Thurman *et al.* 2020), informing subsequent steps in the process related to responding to this now-understood vulnerability. *CCVAs* can include qualitative assessments, which rely on syntheses and expert elicitation (including Indigenous Knowledge); quantitative *response modeling*; and mixed-methods like trait-based assessments that integrate both qualitative and quantitative inputs (Foden *et al.* 2019).

Response modeling (ie building an understanding of how specific climate drivers affect a resource) is a powerful tool for assessing climate-change implications. Response models can take many forms, from conceptual (eg cause-and-effect diagrams) to statistical to mechanistic. The array of *response modeling* tools can be leveraged to address specific objectives and performance metrics identified by resource managers in Step 1. Once built, response models can also be incorporated into *CCVAs* and used in the evaluation and selection of management alternatives (Step 5).

Progress in understanding the trajectory and potential magnitude of climate change continues, yet considerable uncertainties (some irreducible) remain. Rather than relying on individual "predictions" of future conditions and system responses, scenario-based approaches do not assume a "most likely" future and instead bring to bear tools that reflect these uncertainties (Clark-Wolf *et al.* 2025). *CCSP* is an established and effective tool for considering such uncertainties (Reynolds *et al.* 2024), with a history rooted in scenario planning for conservation (Peterson *et al.* 2003) and other sectors (eg private sector, military). Assessing implications of multiple climate futures (Lawrence *et al.* 2021) is a key component of *CCSP* and *SBDA*, and is done through participatory scenario development, *response modeling*, and/or another form of scenario-based *CCVA* (eg Miller *et al.* 2017).

Step 3: review and reconsider management goals

Here, participants review current management goals in the context of climate-change implications (Step 2), initially examining whether the current goal remains feasible and attainable with the existing strategy, such that "business-as-usual" remains viable (Figure 3). If the assessment of climate-change implications (Step 2) indicates that it may be difficult or impossible to achieve the current goal with the existing strategy, then revising the strategy, goal, and/or objective may be necessary. Determining whether the current goal is attainable via a revised strategy (a "climate retrofit") or if both goal and strategy updates may be required (a "climate rebuild") (Figure 3) entails iteration with Step 4 (NPS 2021; Miller *et al.* 2022), wherein conceptual frameworks like *RAD* and *RRT* are used to help fully explore the decision space and consider goal or strategy updates. Step 3 can support uncertainty-informed decision making by drawing on principles from *CCSP* and *SBDA* and documenting where findings regarding goal viability differ among scenarios (Miller *et al.* 2022, 2023).

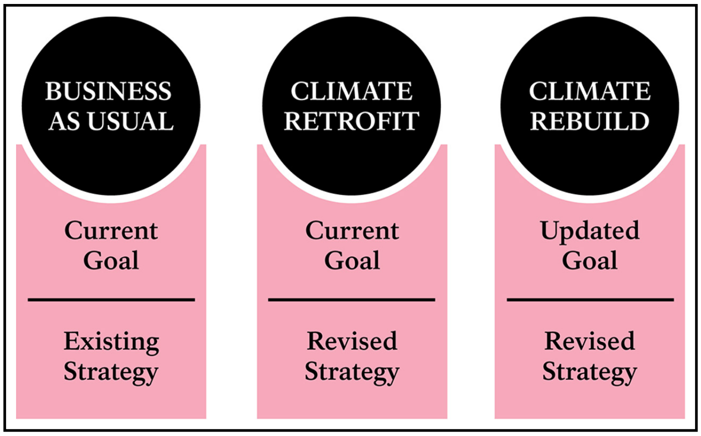

Figure 3. In Step 3, the review of the current management goal and strategy in the context of implications (identified in Step 2) has three possible outcomes, shown here. This step helps align the goal and strategy to ensure that the goal is attainable and includes updating the goal if necessary (NPS 2021 [adapted from Stein *et al.* 2014]).

Step 4: identify potential adaptation strategies

In this step, users employ ideation techniques (Stein *et al.* 2024) to develop alternatives to current strategies, focusing where Step 3 has revealed the need for a climate retrofit or rebuild (Figure 3). Output from Step 2 can be used to develop strategies that reduce exposure or sensitivity or enhance adaptive capacity (Thurman *et al.* 2022). Scenario-based identification of alternatives (consistent with *CCSP* and *SBDA*) may reveal that some strategies address implications of a particular scenario, whereas other strategies may be effective under multiple scenarios and therefore relatively robust to climate uncertainty. The key is creative, open-minded exploration that yields a broad array of strategies for careful consideration in Step 5.

Rapid ecological change and transformation necessitate that candidate strategies span a gradient, from managing for persistence to managing for change (Stein *et al.* 2014). Conceptual frameworks like *RAD* and *RRT*, which have nuanced differences but share a common foundation (ie Millar *et al.* 2007), ensure that options across this gradient are considered through participant-generated or predetermined lists. *Adaptation menus* offer organized, predetermined lists that help users consider a variety of broad strategies and specific actions. So far, thirteen peer-reviewed menus, each with numerous strategies and actions, have been published (NIACS 2025). These menus can help practitioners consider new ideas, avoid reinventing established strategies, and develop a portfolio of actions for a specific area (Swanston *et al.* 2016).

Step 5: analyze and select priority strategies

The fifth step involves the analysis and selection of adaptation strategies for adoption and implementation. *SDM* and *SBDA* apply techniques to support selection of strategies by evaluating their anticipated performance relative to objectives (established in Step 1 and validated or revised under Step 3). The complexity of this assessment is context-specific and should be tailored to the magnitude (reversibility, cost, scope, and so on) of the decision. Performance evaluation begins by predicting the outcomes of alternative strategies under each scenario, often building on *response modeling* from Step 2. Next, the highest-performing strategy is identified by comparing strategy outcomes (eg cost, resource response, robustness to all or a subset of scenarios) using an appropriate analytical method, such as cost–benefit analysis, mathematical optimization, multi-criteria trade-off analysis, portfolio selection, or risk analysis (Runge *et al.* 2020; Hemming *et al.* 2022). Strategy selection entails evaluating a variety of considerations (eg social and legal ramifications, feasibility) and may include preparing to respond to impacts that—based on the scenario-based *CCVA*—are uncertain but plausible.

Step 6: implement priority strategies

Despite growing interest in adaptation, implementation is lagging, particularly for actions that differ from business-as-usual activity or promote transformational change (Wasley *et al.* 2023). Barriers include access to information, financial resources, and workforce capacity (eg Schattman *et al.* 2024). Successful implementation may involve addressing such barriers as well as regulatory requirements (eg US Endangered Species Act or National Environmental Policy Act [NEPA]) and multiple time horizons (short- and long-term goals). Implementation also relates to characteristics of the strategies themselves—while some can be readily implemented (eg minor modifications to existing actions), others might involve complex, collaborative execution (including sequenced steps, triggers, and so forth), such that detailed implementation planning is necessary. Adaptation demonstrations developed using the Adaptation Workbook (Swanston *et al.* 2016) constitute perhaps the most comprehensive set of implemented projects involving an established adaptation process (NIACS 2025).

Step 7: monitor and evaluate strategy effectiveness

The heart of adaptive management is "learning by doing" (Walters and Holling 1990), a mindset that promotes flexible decision making that can adjust to changing environmental and management contexts, which is even more critical when future conditions and trajectories are expected to exceed the historical range of variability. Therefore, monitoring and evaluation (M&E) are essential complements of implementation that foster continuous improvement (Stem *et al.* 2005). Effective M&E can clarify the outcomes of *management actions* (eg changes in system state) and increase preparedness by revealing when thresholds or trigger points are crossed (Ford *et al.* 2013). M&E can support *impact evaluation*: that is, understanding the effects of adaptation strategies and how site-specific characteristics may influence effectiveness (Hansen *et al.* 2023; Stem *et al.* 2005). By extension, and in keeping with the cyclical nature of adaptive management, these insights can be used to refine the scope, goals, and objectives of the next planning cycle (Step 1). Although few empirical examples of adaptation M&E for conservation exist (Hansen *et al.* 2023), there have been recent theoretical advances in approaches for developing goals, indicators, and measurement methods (eg Donatti *et al.* 2020; Pearce-Higgins *et al.* 2022; Peterson St-Laurent *et al.* 2022), and this is a vital area for continued research and development.

Conclusion

As resource managers, adaptation practitioners, and scientists confront ecological change and transformation driven by climate change and its interactions with other forces, the field needs consistent approaches for planning, communicating, and coordinating effective adaptation across boundaries. Our identification of commonalities across existing planning processes and how they relate to various tools is a step toward realizing that vision. The generalized process shared in this paper is not intended to replace existing processes but may be useful for scientists and practitioners in institutions or multi-jurisdictional partnerships lacking a consensus process.

Although relevant to a range of management contexts, these findings do not capture the full breadth of perspectives and knowledges used in resource-stewardship planning. For example, we do not explicitly address the unique considerations of resource stewardship by Indigenous Peoples. Articulating how a breadth of Indigenous approaches (eg relationality, listening circles) relates to the range of Indigenous adaptation planning processes requires careful consideration of how to engage Indigenous Knowledge and protocols effectively and ethically. This valuable work requires a dedicated research endeavor.

As the adaptation community continues to develop new tools and modify existing ones, the field would benefit from clear articulation of how such approaches relate to the broader planning process and established tools. The ideas presented here can serve as a foundation to understand and communicate those relationships. We hope this shared understanding will support adaptation research, planning, and implementation, facilitating communication and coordination across institutions and jurisdictions.

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Data Availability Statement

No data were collected for this study.

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