CONTRIBUTED PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology

WILEY

A practical approach to assessing existing evidence for specific conservation strategies

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Abstract

There is currently a great deal of work being undertaken to collect, analyze, and synthesize available evidence about the effectiveness of conservation strategies. But substantial challenges still remain in enabling practitioners to assess and apply this evidence to their conservation work in an efficient manner. To solve these challenges, there is growing recognition of the need to use situation assessments and theory of change pathways to detail a set of analytical questions and specific assumptions that can be assessed against the evidence base to "make the case" for a proposed strategy and to identify gaps in knowledge. In this study, we first provide updated definitions of some key terms. We then present and provide examples of an approach to enable practitioners to evaluate the evidence base for the critical assumptions that underlie their specific conservation strategies and to wisely use evidence coming from different knowledge systems. This practical approach, which was developed through a series of pilot tests with Parks Canada projects, involves four iterative steps: (1) identify critical questions and assumptions requiring evidence; (2) assemble and assess the specific and generic evidence for each assumption; (3) determine confidence in evidence and its implications; and (4) validate the assessment and iteratively adapt as needed. Ideally, this approach can be integrated into existing decision-making frameworks and can also facilitate better cooperation between researchers who synthesize evidence and practitioners who use evidence to make conservation both more effective and efficient.

KEYWORDS

environmental evidence, evidence-based conservation, evidence-based practice, evidence-informed conservation, natural resource management, Parks Canada, project management

1 | INTRODUCTION

Conservation fundamentally involves implementing *actions* in the context of broader *strategies* designed to achieve desired outcomes (CMP, 2020; Salafsky & Margoluis, 2021). For example, a project team managing endangered seabirds on a small island might design a strategy that involves controlling invasive rat populations to reduce nest predation on the seabirds. Or, a program team trying to deal with the global threat of overfishing might employ a strategy for developing a certification or rating system to promote a sustainable seafood industry.

To help practitioners decide on the best strategies and actions for their situation, there is a growing movement in conservation and in many other disciplines toward *evidence-informed practice*, also known as *evidence-based practice* (Gillson et al., 2019; Pullin & Knight, 2001; Rose et al., 2019; Sutherland et al., 2004). Under this approach, conservation practitioners explicitly make decisions and implement *specific* actions and strategies that are informed by systematic and critical analyses of both their own and the world's previous experiences about what worked, what did not work, and why. Ideally, these practitioners also contribute their specific results to the global evidence base. Over time, this iterative process leads to general principles about the conditions under which a *generic* action or strategy will lead in part or in full to desired outcomes (Salafsky et al., 2019).

There is currently a great deal of work being undertaken to collect, analyze, and synthesize available evidence about the effectiveness of conservation actions and strategies (e.g., Conservation Evidence, Collaboration for Environmental Evidence, Evidensia, Conservation Effectiveness, Conservation Actions and Measures Library). Likewise, there is a growing movement to fully and respectfully utilize Indigenous or Traditional knowledge (IK or TK) in the practice of conservation (e.g., Kadykalo et al., 2021; Reid et al., 2020). But substantial challenges still remain in enabling practitioners to assess and apply all this evidence to their conservation work in an efficient manner. In particular, the approaches used to assess treatment options in evidence-based medicine do not always translate to more complex conservation systems (Salafsky et al., 2021). If medical researchers have a good experimental design and/or sufficient statistical power, they can show a significant causal relationship between implementation of Treatment X and achievement of Desired Outcome Y without necessarily understanding the underlying treatment mechanism (Moodie & Krakow, 2020; Thomas D. Cook, personal communication). It is more problematic, however, to apply this "black-box" approach to medical situations in which there is more individual variation (e.g., the adaptive treatment strategies described by

Moodie & Krakow, 2020). And this is likewise a problem for many conservation strategies that take place in complex ecological and socio-economic systems and involve different combinations of actions, multiple intermediate outcomes, long time frames, and a host of confounding variables (Salafsky et al., 2021). In these cases, if a strategy results in the desired outcome, it is hard to know with confidence that this outcome was "caused" by implementation of the strategy. And if the desired outcome was not obtained, it is difficult to figure out why the strategy did not work and what could be done to improve its implementation.

To address this problem, in both medicine and in conservation, there is a growing movement toward assessing evidence in the context of decision-relevant questions (Goode et al., 2011, Richardson et al., 1995, Sackett, 1997, USAID, 2020). In particular, there is increasing recognition of the need to use situation assessments and theory of change pathways to articulate the mechanism by which a given strategy is assumed to lead to intermediate results and ultimate desired outcomes (CMP, 2020; GEF, 2019; Salafsky & Margoluis, 2021). This analysis ultimately involves detailing a set of *analytical questions* and specific *assumptions* that can be tested against the *evidence base* to "make the case for" or "refute" the proposed strategy (see our definition of these terms below).

Salafsky et al. (2019) recently published a framework for defining and using evidence in conservation practice. In this study, we build on and extend this earlier work to present an approach to enable practitioners to develop and evaluate the existing evidence base for the critical questions and assumptions that underlie their specific conservation strategies. Our aim is to provide a flexible approach that can support a range of simple to more rigorous evidence assessments. It is also our expectation that this approach could enable inclusion of all types of evidence including both Western scientific and Indigenous and Traditional ways of knowing. Ideally, this practical approach can be integrated into existing decision-making frameworks and can facilitate better cooperation between researchers who synthesize evidence and practitioners who use evidence to make conservation both more effective and efficient.

2 | METHODS

This work began with the definitions of key terms and approach for using evidence originally presented in Salafsky et al. (2019). We piloted this framework with a set of four conservation projects being implemented by Parks Canada and partners through the Conservation and Restoration (CoRe) funding program (Table 1). Along the way,

TABLE 1 Summary of pilot projects used to develop and test the approach in this study

Pilot project	Description	Previous experience	Resource investment
Gwaii Haanas Seabirds—The SGiin Xaana Sdiihltl'lxa—Night Birds Returning Project	Restoration of Ancient Murrelet seabirds in Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site. This project was co-developed with the Haida Nation through the co-management board that governs Gwaii Haanas and involves incorporating Indigenous knowledge.	This pilot involved retrofitting past work and creating a summary of evidence to inform future restoration work. It was able to leverage many years of experience that the project lead had at this site.	~20 person-h developing initial assumptions ~20 person-h assembling and assessing evidence
Atlantic Salmon—Return of the King: Evaluating and Adapting Proven Methods in Endangered Salmon Restoration for Broad-Scale Benefits	A multi-park Atlantic salmon restoration project including Fundy, Kouchibouguac, Cape Breton Highlands, Gros Morne, and Terra Nova National Parks.	This pilot involved ongoing work. It was able to leverage many years of experience that the project leads had at these sites.	~25 person-h developing initial assumptions ~20 person-h assembling and assessing evidence
Waterton Trout—Conserving Waterton's Aquatic Communities	An initiative to conserve aquatic Species at Risk communities and restore impaired aquatic ecosystems in Waterton Lakes National Park. The program focuses on restoring westslope cutthroat trout, bull trout, and native amphibian ecosystems, and reducing the risk of aquatic invasive species.	This pilot involved ongoing work. It was able to leverage several years of experience that the project lead had at this site.	~20 person-h developing initial assumptions ~15 person-h assembling and assessing evidence
Jasper Caribou—Adoption of a Conservation Breeding Strategy to Enable Recovery of Caribou Populations in Jasper National Park	A proposed strategy to use conservation breeding and herd augmentation to promote recovery of Southern Mountain Woodland Caribou in Jasper National Park.	This pilot was applied to a proposed strategy. It was able to leverage many years of experience that the project leads had at this site as well as extensive work to prepare for the potential implementation of the conservation breeding strategy.	>100 person-h from five-person core team developing initial assumptions & evidence >600 person-h from 30+ person expert review panel providing assessing the initial assessments

we adapted the definitions and approach based on our findings as well as a review of related efforts (see Table S1), resulting in the version of the approach presented in this study. We illustrate our approach with a simplified fictitious example that is drawn from several real-world rat-eradication projects; the actual results for all four pilot projects are available in Irvine et al. (2021) and Foundations of Success and Parks Canada (2021), appended as Appendices S1 and S2. Our approach was also separately tested in part by Parks Canada during a process to decide on how to treat a potential Spruce Budworm outbreak in Gros Morne National Park (Foundations of Success & Parks Canada, 2021).

3 | DEFINITIONS OF KEY TERMS

For the purposes of this study, we are assuming that the *practice of conservation* (which includes natural resource management) takes place through specific *projects* and broader *programs* (CMP, 2020). Conservation is a process that involves a defined *project* or *program team* first agreeing on its desired *goals* with regard to a given *system of interest* and then deciding on, implementing, and managing one or more *strategies* that involve taking particular *actions* that are designed to achieve these goals. This process, which can be applied at any spatial or temporal scale, is implemented through various planning
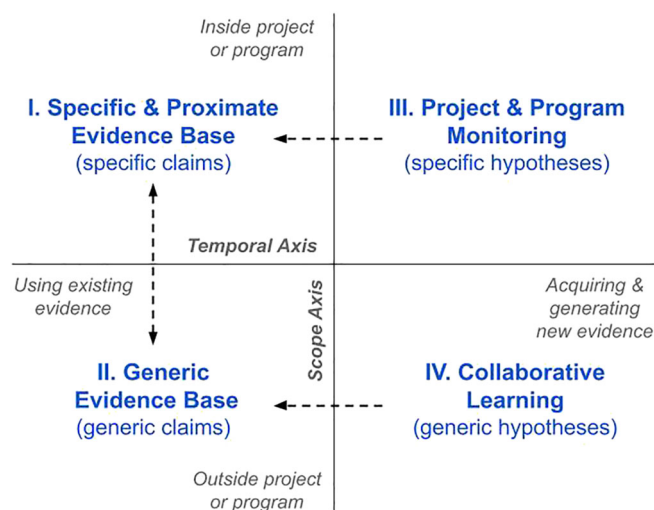
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FIGURE 1 Sources of evidence and corresponding types of assumptions (claims and hypotheses) for a conservation project or program. Adapted from Salafsky and Margoulis (2021)

and decision support frameworks (Schwartz et al., 2017).

Building on Salafsky et al. (2019) and Salafsky and Margoluis (2021) we can define the following.

- *Analytical Question*—Something that we need to know about a system.
- *Assumption*—Something that we believe to be true about a system; often a more detailed "assessable" articulation of an analytical question of interest.
- *Evidence*—The relevant data, information, knowledge, and wisdom used to assess an assumption.

Note that in our definition of evidence, we are deliberately substituting the term *assumption* for Salafsky et al.'s (2019) original use of the term *hypothesis* and Irvine et al.'s (2021) and Salafsky and Margoluis's (2021) use of the term *claim*. This evolving definition reflects that we now recognize two types of assumptions, each with different sources of evidence.

- *Claim*—An assumption about a system that is supported by *existing evidence* (the left-hand side of Figure 1).
- *Hypothesis*—An assumption about a system that requires *new evidence* from future *evidence synthesis, monitoring, collaborative learning*, or *research*, articulated in *future information needs* (the right-hand side of Figure 1).

Following Dubois et al. (2019), in theory assessing a claim generally takes place before a management decision has been made, whereas testing a hypothesis involves learning from the outcomes after a management decision has been made and a strategy has been implemented and monitored. But in practice there is often a confusing overlap between claims and hypotheses—for example, if there is partial existing evidence for an assumption, is it a claim or a hypothesis? To avoid any further confusion, in this study and in our approach, we now exclusively use the more general and practitioner-friendly term *assumptions* to encompass both claims and hypotheses.

Assumptions themselves can also be subdivided into the following.

- *Specific assumption*—A proposition about a specific case situation (often within the system of interest), such as "*Rats are the primary cause of seabird nest predation on the islands within our project scope*" or "*An outreach campaign to our local community members can persuade them to install rat barriers on their boats.*"
- *Generic assumption*—A proposition about a generic situation that is often a composite of many specific case situations, such as "*Rats are a primary cause of seabird nest predation on islands around the world*" or "*Outreach campaigns will change target audience attitudes and behaviors.*"

This distinction between specific and generic assumptions is important because a conservation team ultimately needs to assess specific assumptions about its specific system of interest, but most external evidence is about analogous generic assumptions (Figure 1).

Evidence can likewise be described in terms of:

- *Source of evidence*—Raw data, analyzed information, synthesized knowledge, and distilled wisdom. Note that all of these sources can include both Western scientific and Indigenous and Traditional ways of knowing.
- *Evidence base*—The body of all existing data, studies, syntheses, and theory being used as sources of evidence for a particular set of assumptions.

Within a given evidence base for an assumption, we can classify different sources of evidence in terms of its relation to a system of interest:

- *Specific evidence*—Evidence from the specific system of interest. Examples include data from camera trap studies that show rats are the primary cause of seabird nest predation on one of the islands within your project scope, Traditional Knowledge shared by knowledge holders describing the locations of traditional harvest of seabird eggs and the decline in that practice

commensurate with the spread of rats, or an organizational report about an outreach campaign in your project area to get fishing boat operators to adopt sustainable fishing practices (i.e., a different desired behavior).

- *Proximate evidence*—Evidence that may not be from your specific system or program but is from a spatially or conceptually close situation that makes it potentially more relevant than evidence from the other side of the country or the world. Examples include data from camera trap studies that show rats are the primary cause of seabird nest predation on nearby islands, the fact that the local First Nations language or culture does not contain a pre-colonization word or stories or dances about the invasive species, or an organizational report about an outreach campaign in a nearby district to get fishing boat operators to adopt sustainable fishing practices. Note that the boundaries between proximate and generic evidence can be somewhat arbitrary and fuzzy.
- *Generic evidence*—Evidence from the rest of the world about relevant systems or programs. Examples include a systematic review showing that rats are a primary cause of seabird nest predation on islands around the world or summaries of various strategy pathways around the world seeking to use outreach campaigns to change boat owner attitudes and behaviors about installing rat barriers.

Again, building on the definitions and Figure 1 in Salafsky et al. (2019), we can define the *Degree of Support for a Specific Assumption* as a combination of:

- *Direction of effect*—Whether the evidence supports or argues against the case for an assumption. *Supporting* (or *positive*) *evidence* builds the case for an assumption; *refuting* (or *negative*) *evidence* reduces the case for an assumption, *mixed evidence* refers to an evidence base in which there is a blend of positive and negative evidence.
- *Strength of effect*—The degree of support for or against the case for an assumption. *Strong evidence* convincingly supports or refutes an assumption, *weak evidence* only somewhat supports or refutes an assumption.

Likewise, we can define the *Weight of Evidence Base for a Specific Assumption* as a combination of:

- *Reliability*—The quality of the evidence source or overall evidence base. *More reliable evidence* comes from a higher quality source or evidence base and has higher internal validity and credibility (e.g., a systematic review, a controlled study, or a community-selected

trustworthy source of Traditional Knowledge); *less reliable evidence* comes from a lower quality source or evidence base and has lower internal validity and reliability (e.g., a single case study or an anecdote). Note that our definition of "reliability" here is intentionally broader than the strict technical definition of this term in statistics.

- *Relevance*—The degree to which the source of evidence applies to the specific assumption being made. *More relevant evidence* addresses the assumption in question and matches key enabling conditions (parameters of the situation of interest that may affect the assumption, such as the local rainfall patterns or the government's land tenure policies). *Less relevant evidence* less directly addresses the assumption or does not match key enabling conditions.

In turn, the *Degree of Support for a Specific Assumption* and the *Weight of Evidence Base for a Specific Assumption* can be combined to create the *Level of Confidence in a Specific Assumption* (per the matrix in Figure 5).

Finally, building on Salafsky and Redford (2013) and Salafsky and Margoluis (2021), we can define:

- *Required level of proof*—The level of confidence in the evidence needed to make the case for an assumption in relation to risk. In most conservation cases, the *burden of proof* lies with the entity responsible for taking action in a given situation. Their *standard of proof* is typically established for the overall situation, rather than any one specific strategy or action and depends on the nature of the assumption being made, the consequences of the decision, and the relative risks of action (Type I error) versus inaction (Type II error). For example, if a project is managing the last remaining population of an endangered species, or if the project will dramatically impact the lives of many stakeholders, then the project will require a higher level of proof than projects with lower stakes and/or consequences.

4 | APPROACH FOR ASSESSING THE EVIDENCE FOR A SPECIFIC CONSERVATION STRATEGY

Here, we present a four-step practical approach for assessing the existing evidence for a specific conservation strategy.

Step 1. Identify critical questions and assumptions requiring evidence.

Step 2. Assemble and assess the specific and generic evidence for each assumption.

TABLE 2 Excerpt of Evidence Capture Sheet Showing Rat Eradication Project's assumptions and evidence after Step 2A

#1 Questions / Assumptions	#2 Who, date	#3 Evidence base for assumptions	#4 Degree of support direction & strength	#5 Weight of evidence reliability × relevance	#6 Confidence in assumption support × weight	#7 Criticality of assumption	#8 Additional information needs	#9 Review validation
Question A: Do our seabird populations require conservation action?								
A1. Seabird populations on our islands are globally important	Team, Aug 21		Not clear	None	Need more info		Check on global status.	
A2. Seabird populations on our islands have low viability status	Team, Jun 21	SE: Annual quick surveys show seabird pop rapidly declining on 4 of 7 islands.	Strongly supports	Low	Need more info		Need to do more research on seabird vulnerability to rats.	
A3. Seabirds historically were a culturally important food source	Team, Jan 21	SE: Indigenous elders (recognized as knowledge holders by their community) describe traditional harvests.	Strongly supports	High	Very confident			
Current confidence in evidence for overall question (*based on Critical Weakest Link*)								
Question B: Are rats a major threat to our seabird populations?								
B1. Nest predation is the major source of seabird mortality	Team, Sep 21	SE: Camera monitoring shows raccoons are spreading on islands. PE: Recent unpublished research on nearby islands shows adult seabird survival drops from 77% to 52% when raccoons are present (Parks Canada, 2020).	Refutes	Medium	Need more info		There seems to be more than just nest predation; need to monitor presence, interactions, and impacts of raccoons. What about other threats?	
B2. Rats are the primary cause of nest predation	Team, Jan 21	SE: Test traps have shown rats present on the 4 islands. PE: Agency records + lit review show in islands where have been unmanaged, they led to severe seabird population declines (Parks Canada, 2020).	Weakly supports	High	Confident, but...		It is clear rats are a cause, but not clear they are the primary cause.	
Current confidence in evidence for overall question (*based on Critical Weakest Link*)								

TABLE 2 (Continued)

#1 Questions / Assumptions	#2 Who, date	#3 Evidence base for assumptions	#4 Degree of support direction & strength	#5 Weight of evidence reliability × relevance	#6 Confidence in assumption support × weight	#7 Criticality of assumption	#8 Additional information needs	#9 Review validation
B3. Other sources of nest predation are less of an issue	Team, Jan 21	SE: Seabirds have evolved with ravens, raptors, and otters.	Weakly supports	Low	Need more info			
B4. Marine vessels are the major cause of rat re-introductions to our islands	Team, Aug 21	SE: Despite prohibitions, there are reports of boats landing on islands.	Not clear	None	Need more info		Need to learn more about this.	

Abbreviations: GE, generic evidence; PE, proximate evidence; SE, specific evidence.

Step 3. Determine confidence in evidence and its implications.

Step 4. Validate the assessment and iteratively adapt as needed.

We illustrate this approach using a fictionalized version of the rat eradication project. This example draws from several specific rat eradication restoration projects around the world, but is simplified to illustrate the method. Although we present this approach in four discrete steps, in practice these are not a linear sequence of "waterfall" subroutines so much as a guide to a highly iterative "agile" process. As we discuss in more detail in Table S1, this approach is similar to, but has some key differences from the *5As Approach for Evidence-Based Practice* (Ask, Acquire, Appraise, Apply, Assess) originally developed in evidence-based medicine (Richardson 2005 as cited in Goode et al., 2011).

4.1 | Step 1. Identify critical assumptions requiring evidence

Per our definitions above, evidence only makes sense in the context of *critical assumptions* about *analytical questions* of interest. In particular, when dealing with conservation strategies, these questions include whether a given strategy will work in the context of the project situation, and also how the strategy compares to other potential strategies. To this end, the first step involves identifying the analytical questions and critical assumptions requiring evidence assessment.

For example, there are at least five critical questions that need to be addressed to make the overall case for the proposed rat eradication strategy:

A. Do our seabird populations require conservation action?

B. Are rats a major threat to our seabird populations?

C. Is the proposed rat eradication strategy feasible and effective?

D. Are alternative rat control strategies less feasible and/or effective?

E. Can we keep rats from re-invading the islands?

The assumptions inherent in all five questions need to be substantiated to "make the case" for the proposed rat eradication strategy.

As a rule, assumptions are easier to assess if they are specific and well formulated. For example, rather than assessing the broad assumption that *rats are the major threat to our seabird populations*, it is better to formulate a set of more assessable specific assumptions such as *nest predation is a major cause of seabird mortality, rats are*
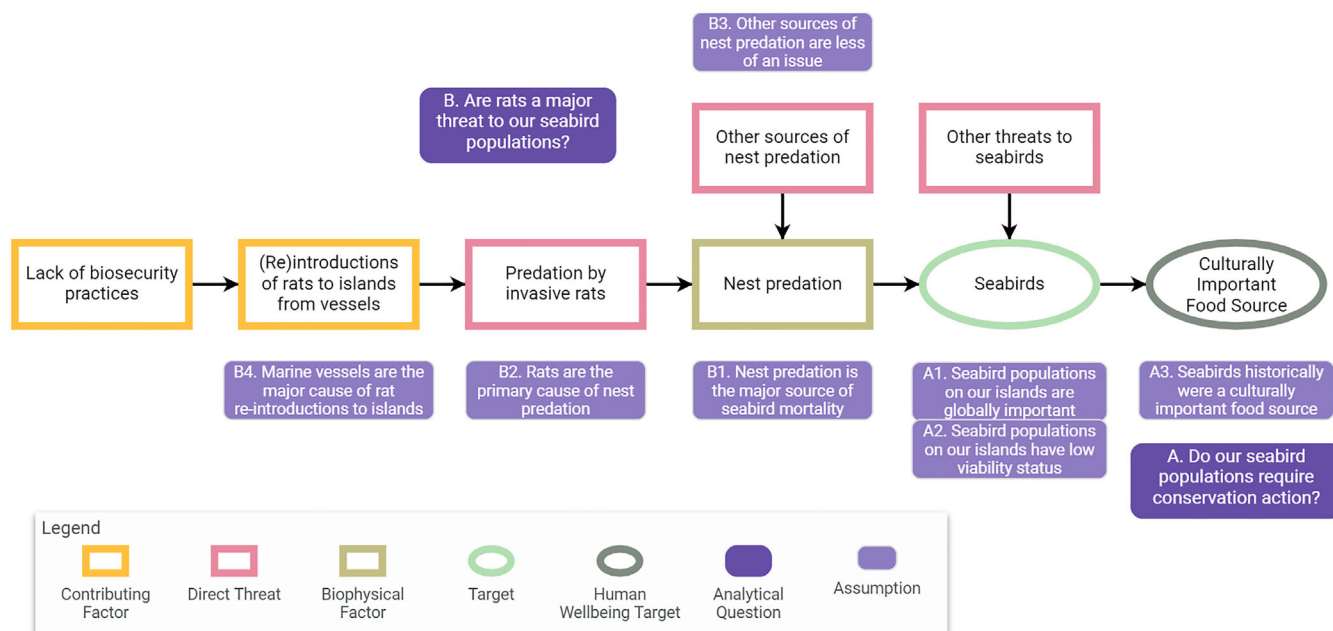
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FIGURE 2 An excerpt from the fictitious Rat Eradication Project's situation assessment showing analytical questions and assumptions. This example is derived from several different real-world rat eradication projects. Situation assessments are typically most useful to consider assumptions related to the need for taking action based on the status of targets and threats in the system
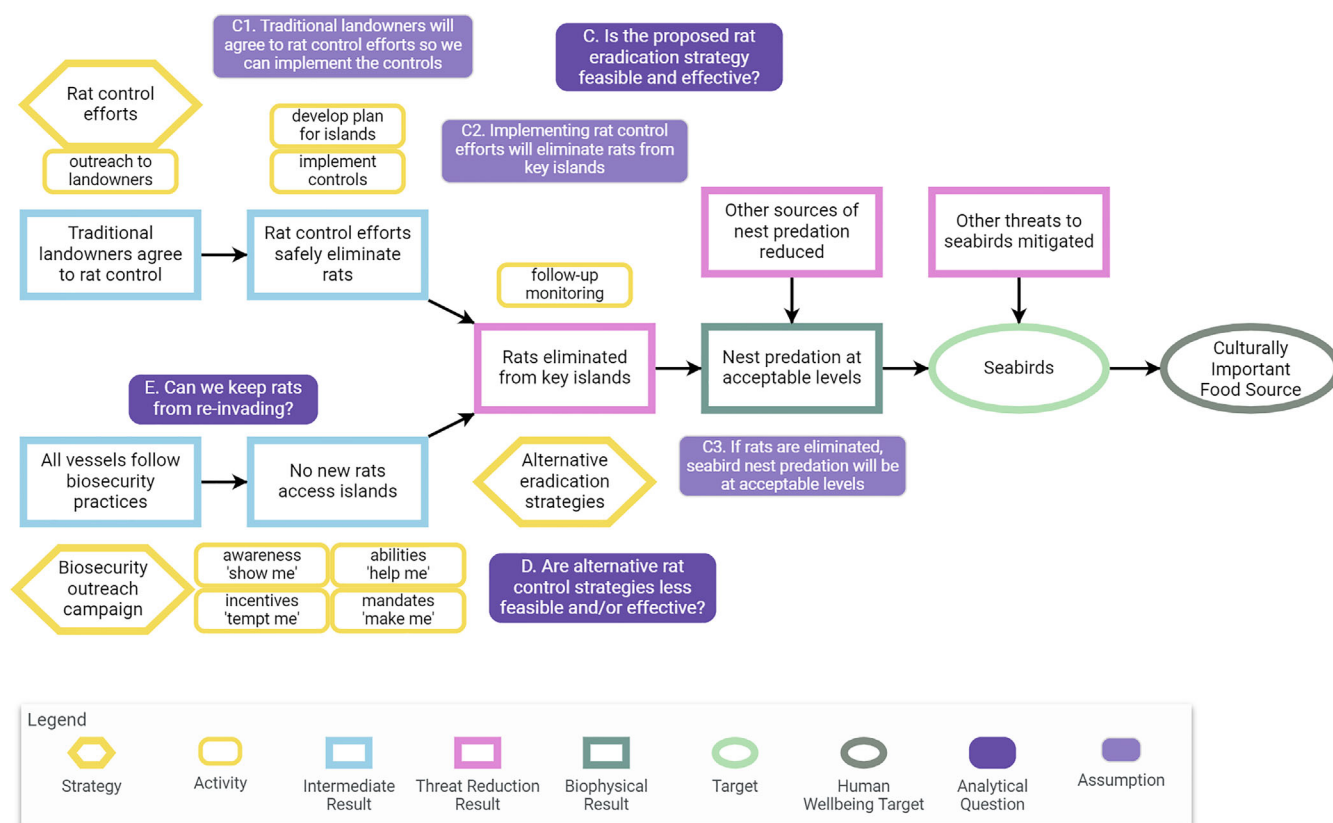

FIGURE 3 The Rat Eradication Strategy theory of change pathway showing analytical questions and assumptions. This example is derived from several different real-world rat eradication projects. Note assumptions for Questions D and E are not shown. Theory of change pathways are typically most useful to consider assumptions related to the effectiveness of specific strategies
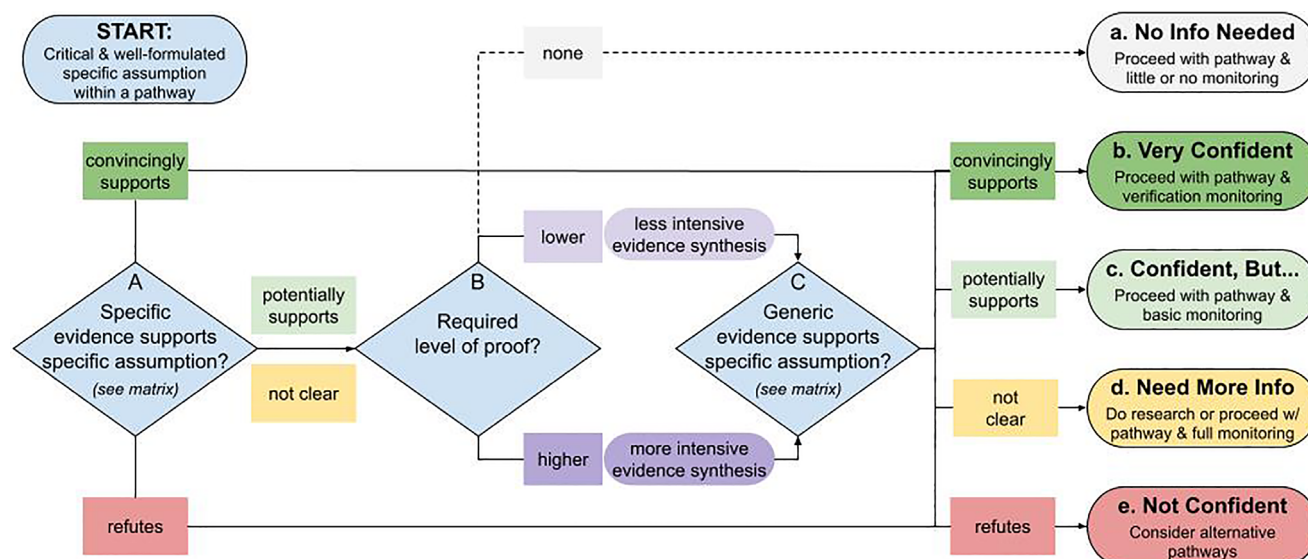
FIGURE 4 Process for assembling and assessing the evidence base for a given assumption

FIGURE 5 Matrix used to combine *Degree of Support for Assumption* × *Collective Weight of Evidence Base* to determine *Confidence in Assumption*

the primary cause of seabird nest predation, and *other sources of nest predation are less important*. To this end, it is usually helpful to break down each question into a set of component assumptions. Column #1 of Table 2 lists some examples of the questions and assumptions for the rat eradication example.

The process of identifying and prioritizing questions and assumptions is at least as much an art as it is a science. Dozens or even hundreds of assumptions can be made about any project or strategy. The challenge is to determine which ones need to be assessed and to what degree. This process can be difficult if you are starting from a blank slate

but is much easier if you can think in terms of your project's analytical framework. Specifically, your project's situation assessment (Margoluis et al., 2009) shown in Figure 2 and theory of change pathway (GEF, 2019; Margoluis et al., 2013) shown in Figure 3 provide good guides for developing the questions and assumptions for a given strategy.

Technically, every factor and every link between factors in your situation models and strategy pathways represents an assumption you are making. The very act of adding a factor or a link between factors to your model means that you are making one or more assumptions

TABLE 3 Excerpt of Evidence Capture Sheet Showing Rat Eradication Project's assumptions and evidence after Step 2C

#1 Questions / Assumptions	#2 Who, date	#3 Evidence base for assumptions	#4 Degree of support direction & strength	#5 Weight of evidence reliability × relevance	#6 Confidence in assumption support × weight	#7 Criticality of assumption	#8 Additional information needs	#9 Review validation
Question A: Do our seabird populations require conservation action?					**Current confidence in evidence for overall question** *(based on Critical Weakest Link)* **Confident, but...**			
A1. Seabird populations on our islands are globally important	Team, Aug 21	GE: IUCN species maps show that over 35% of the global breeding population is on 7 program islands (IUCN, 2019).	Strongly supports	High	Very confident	Not critical		Agree
A2. Seabird populations on our islands have low viability status	Team, Jun 21	SE: Annual quick surveys show seabird pop rapidly declining on 4 of 7 islands. GE: Research shows seabirds have a low fledging rate (1.4–1.6 chicks per pair) and are thus vulnerable to fast breeding invasive predators (Smith et al., 2017).	Strongly supports	Medium	Confident, but...	Essential	Need to do more intensive status monitoring	Conditionally agree
A3. Seabirds historically were a culturally important food source	Team, Jan 21	SE: Indigenous elders (recognized as knowledge holders by their community) describe traditional harvests.	Strongly supports	High	Very confident	Less critical		We lack expertise to assess
Question B: Are rats a major threat to our seabird populations?					**Current confidence in evidence for overall question** *(based on Critical Weakest Link)* **Need more info**			
B1. Nest predation is the major source of seabird mortality	Team, Sep 21	SE: Camera monitoring shows raccoons are spreading on islands. PE: Recent unpublished research on nearby islands shows adult seabird survival drops from 77% to 52% when raccoons are present (Parks Canada, 2020).	Refutes	Medium	Need more info	Essential	There seems to be more than just nest predation; need to monitor presence/impacts of raccoons. Also need to think about climate change impacts.	Agree

TABLE 3 (Continued)

#1 Questions / Assumptions	#2 Who, date	#3 Evidence base for assumptions	#4 Degree of support *direction & strength*	#5 Weight of evidence *reliability × relevance*	#6 Confidence in assumption *support × weight*	#7 Criticality of assumption	#8 Additional information needs	#9 Review validation
B2. Rats are the primary cause of nest predation	Team, Jan 21	GE: Seabirds are increasingly vulnerable to climate-change linked food shortages (BirdLife, 2020). SE: Test traps have shown rats present on the 4 islands. PE: Agency records + lit review show in islands where rats have been unmanaged, they led to severe seabird population declines (Parks Canada, 2020).	Weakly supports	High	Confident, but...	Essential	It is clear rats are a cause, but not clear they are the primary cause.	Disagree
B3. Other sources of nest predation are less of an issue	Team, Jan 21	SE: Seabirds have evolved with ravens, raptors, and otters.	Weakly supports	Low	Need more info	Critical		Insufficient info presented
B4. Marine vessels are the major cause of rat re-introductions to islands	Team, Aug 21	SE: Despite prohibitions, there are reports of boats landing on islands. GE: Literature shows boats are a major source of rat vector, but that rats can also cross this distance on natural rafts (Lee et al., 2018). GE: Literature shows that re-invasion can be facilitated by the prior presence of eradicated invasives (Banks et al., 2018).	Mixed	Medium	Need more info	Critical	Need to ensure rats cannot raft over from nearby islands.	Divergent opinions in group

Abbreviations: GE, generic evidence; PE, proximate evidence; SE, specific evidence.

TABLE 4 Summary of current evidence for analytical questions

#1 Analytical question	#2 Who, date	#3 Summary of current evidence for question	#4 Current confidence in evidence	#5 Implications	#6 Additional information needs
A. Do our seabird populations require conservation action?	Team, Jun 2021	Over the past decade, seabird viability on our islands has declined from good to fair and this trend seems to be continuing. This is consistent with situations in other similar sites, warranting action.	Very confident	Take immediate action. Continue to monitor seabird status.	Continue tracking viability indicators.
B. Are rats a major threat to our seabird populations?	Team, Dec 2021	Although various threats were responsible for the historical decline of the seabird population, both local observations and a review of experiences from other similar sites indicate that rat nest predation is a major threat. Raccoons also emerged as a potential threat that needs to be better understood.	Confident, but...	Figure out what action(s) to take to deal with rats. Investigate impact of raccoons.	Continue tracking rat predation levels. Investigate the impact of raccoons through lit review / on-site monitoring.
C. Is the proposed rat eradication strategy feasible and effective?	Team, Jun 2021	While it is clear from other sites that rat eradication would be technically feasible in the short-term, it is not yet clear whether this will be socially acceptable given the potential lack of durability of the solution.	Need more info	Explore with the community whether eradication is acceptable.	Compare rat population levels in treated and untreated areas. Conduct key informant interviews with tribal elders.
D. Are alternative rat control strategies less feasible and/or effective?	Team Nov, 2021	Our experience is that that other means of controlling rats such as trapping or introducing natural predators would not be technically feasible in our islands.	Confident, but...	Continue to monitor the emergence of new strategies that may be more effective.	Stay abreast of new literature / examples of rat eradication strategies.
E. Can we keep rats from re-invading?	Team, Dec 2021	It is not clear whether it is feasible to keep rats from re-invading; experience from other sites is that this requires a major investment of resources and that re-invasion may actually be facilitated by the previous invasive species.	Not confident	Unless we can figure out how to solve this problem, eradication will only be a temporary fix at best.	Stay abreast of new literature / examples of biosecurity strategies.

about it. But you cannot expect to collect evidence for every last assumption. Instead, you want to prioritize the assumptions that are truly *critical* to your overall argument. In particular, you want to focus on the assumptions that are essential to the line of reasoning in a pathway, are more uncertain, have higher risk consequences, or some combination of all these considerations. If an assumption is more peripheral to your main pathway or you and your partners are reasonably confident in your understanding of the assumption, then you probably do not need to spend much time searching for and analyzing evidence about it. Keep in mind that almost all assumptions could arguably be somewhat critical; if they were not meaningful, you probably would not have included these factors and relationships in your models. But the art lies in knowing which assumptions would benefit from a more intensive assessment of the existing evidence.

4.2 | Step 2. Assemble and assess the specific and generic evidence for each assumption

The starting point for this step involves identifying a specific assumption that requires evidence. Per the above discussion, if an assumption is not critical and well-formulated, it is probably not worth spending time on developing evidence for it.

As shown in the process flow chart in Figure 4 and matrix in Figure 5, assembling and assessing the evidence base for each critical assumption is an iterative process that involves answering three questions as you develop your Evidence Capture Sheet (Tables 2 and 3).

A. *Specific evidence supports specific assumption?* This first question asks you to assemble existing specific and proximate evidence sources (as well as any readily available generic evidence sources) and determine to what degree this available evidence base supports the assumption. Basically, before investing substantial time and treasure in collecting and assessing additional evidence, you should see what you and your team already know about your assumption based on your previous experiences and accumulated knowledge. If this available evidence base convincingly supports the assumption, then you can move on to the next assumption. And likewise, if you know based on available evidence that the assumption is refuted, then you should also move on and consider alternative pathways. The bottom line is that if your specific and proximate evidence enables you to be sure about the assumption one way or the other, you do not need

to spend time looking for additional evidence. But if the available evidence only potentially supports the assumption or if it is not clear, then you need to expand your evidence base. For example, in Column #1 in Table 2, the Seabird Project team has listed the major assumptions they are making in their rat eradication pathway. They have then entered the available project specific and proximate evidence sources for each assumption (Column #3), made initial determinations of the *Degree of Support* (Column #4) and *Weight of Evidence* (Column #5) for each assumption, and then used this to calculate the *Initial Confidence in the Specific Assumption* (Column #6). The team determines that they have sufficient evidence to move forward with some of the assumptions, but that the remaining assumptions will require additional evidence per the comments (Column #7)

B. *Required level of proof?* The second question determines how much investment your team should make in additional evidence collection and assessment based on the level of proof situation you are facing and thus the consequences of making the wrong decision. If you are in a low level of proof situation, then you do not need to spend a great deal of time compiling and synthesizing evidence. But if you are in a higher level of proof situation, then you probably need to invest more resources in collecting and weighing available evidence. For example, in both the fictionalized and real-world versions of the Seabird Project, because this work involved an important breeding area for a species at risk, the project team decided this entire strategy required a medium level of proof. By contrast, in the Caribou Breeding project, because this project involved the last remaining animals in a subpopulation, required a large expenditure of resources, and had a high profile across many stakeholder and rightsholder groups, this strategy required a high level of proof

C. *Generic evidence supports specific assumption?* The third question asks you to gauge the extent to which external evidence supports your specific assumption. In some situations, there may already be existing evidence syntheses such as systematic reviews and maps (e.g., CEE, 2018), subject-wide evidence syntheses (e.g., Sutherland et al., 2018; Sutherland & Wordley, 2018), or other evidence synthesis projects completed by specialists and Knowledge Holders who have the skills and training to do this work while minimizing potential bias. In other situations, however, it may be necessary for the team to do its own search, assembly, screening, and weighting of available evidence while respecting data sovereignty. A range of techniques are available for each of these

tasks (CEE, 2018; Cook et al., 2017; Suter, 2016; Sutherland et al., 2018). Fundamentally, however, these techniques involve searching for and assembling available sources of evidence. Each source is then assessed in terms of its *Degree of Support* for the assumption (direction × strength of the effect) and its *Weight of Evidence* (reliability × relevance), and then all sources in the evidence base are placed on the balance to arrive at a determination of the *Final Confidence in the Specific Assumption*. There is inevitably a tradeoff between investing in more systematic evidence search and synthesis techniques, which can reduce the potential for bias introduced by "cherry picking" your sources of evidence, versus doing this work more expediently (Grainger et al., 2020). Where you land on this spectrum depends in large part on your anticipated return on investment in obtaining more information and whether you are in a higher or lower level of proof situation. For example, in Table 3, the Seabird Project team has now added the relevant generic sources of evidence to their key assumptions. In this case, they did not conduct a systematic review of the evidence, but relied on the project leads to find the relevant sources.

4.3 | Step 3. Determine confidence in evidence and its implications

Once you have assembled and assessed the evidence base for a given assumption, then the next step is to determine your *Final Confidence in the Specific Assumption*. As shown in the left-hand side of Figure 4, there are five potential endpoints from this decision tree, each of which has different implications for how you proceed with both the proposed strategy as well as the ongoing monitoring of this work:

a. *No more information needed*: If you are in a very low level of proof situation, it is probably not worth spending resources on evidence synthesis or monitoring.

b. *Very confident*: If you are very confident in your assumption, you can proceed to the next assumption in your analysis and ultimately to implementation of your strategy. You will probably have to invest in only minimal verification monitoring to ensure that the strategy is working as predicted.

c. *Confident, but...*: If you are confident but not absolutely sure in your assumption, you can also proceed to the next assumption in your analysis and ultimately to the implementation of your strategy. Here, however, you will probably have to invest a

bit more in effectiveness monitoring of your strategies and/or the status of key factors in your situation assessment.

d. *Need more information*: If you are truly not confident in the evidence for your assumption, then you need to invest in acquiring and assessing more evidence to address your specific knowledge gap. This could take the form of looking for additional existing evidence or conducting needed research. Or if action is more urgent, you can choose to take action, but you then need to invest in more rigorous adaptive management to collect monitoring data to meet these information needs.

e. *Not confident*: Finally, if you are confident that your assumption is refuted by the available evidence, then you should consider either alternative subpathways within a given model or perhaps even an alternative set of actions with different pathways. You may also want to defer action altogether. But you should not invest more in collecting evidence for this assumption.

Returning to Table 3, the team has now compiled and rated additional external sources of evidence. These have resulted in the final confidence ratings for the specific assumptions. In addition, the team notes several evidence gaps which lead to the *Additional Information Needs* in Column #8, which will become the basis for monitoring and learning hypotheses.

Once you have determined the *Final Confidence* in each assumption, you need to aggregate these ratings to determine the *Final Confidence* in the evidence for a given question. Following the principle that "a chain is only as strong as its weakest link," as a general rule, the *Final Confidence* in the evidence for a given question could be the same as its lowest rated sub-assumption. However, if a given sub-assumption is not truly a critical part of the case for an overall question per Column #7, then it may make sense to ignore its rating under a "weakest critical link" approach. Going forward, it may also be necessary to develop more nuanced aggregation rules to accommodate different situations.

Returning to Table 3, the team aggregates the various assumptions to get the rating for each of the questions. The evidence for these questions is then summarized in Table 4, which presents the overall case being made for the strategy as well as the ongoing *Management Implications* for their work and their *Additional Information Needs*.

4.4 | Step 4. Validate the assessment and iteratively adapt as needed

The final step in the approach is to take a step back and check your work. If your situation requires a lower level

of proof, you might just want to ask a few peers to review and provide feedback on your Evidence Capture Sheet. But if your situation requires a higher level of proof, it may also be helpful to have outside parties more formally validate your evidence analysis. In these cases, it can be helpful to add additional columns to your Evidence Capture Sheet to show the review assessment as shown in Column #9 in Table 3. Based on the reviewer feedback, you may need to iteratively go back and adjust your ratings of the evidence or even reformulate your assumptions and questions.

In the three pilot studies with lower level of proof requirements, we primarily relied on limited peer review feedback. However, in the Caribou Project, which required a high level of proof, we conducted an extensive review process in which we received feedback from over 30 experts. This feedback was compiled and incorporated into our Evidence Capture Sheet, as shown in Annex 2 of Foundations of Success and Parks Canada (2021). The additional test case Gros Morne Spruce Budworm project, which likewise required a higher level of proof, also conducted an extensive external peer review, bolstering management confidence in the final decision.

5 | RESULTS FROM PILOT TESTS

The specific results from each of our four pilot projects are available in Irvine et al. (2021) and Foundations of Success and Parks Canada (2021).

In follow-up discussions, the pilot project teams generally agreed that the evidence assessment approach seemed both useful and practical. They reported that:

- Identifying assumptions in the context of a project's situation assessment and strategies helped them break down the larger project into smaller components in a logical order that helped clarify connections and opportunities.
- The Evidence Capture Sheets provided a useful format to compile evidence and identify additional evidence needs at different levels of rigor.
- The approach helped them highlight where they needed to spend time getting more information about their project and strategies.
- The approach gave them an opportunity and the motivation to document how their team made decisions and "get this information out of the project team's heads" in a distilled and logical format.
- This documentation also enabled practitioners to more effectively communicate and justify their work to senior leadership and decision makers.

- The process provided good opportunities to have peer review of their projects from an outside perspective.

The project teams also had several concerns and suggestions for improvement about this approach including that:

- It would be difficult to undertake this approach if a team does not have experience in the type of strategic thinking encompassed in the *Open Standards for the Practice of Conservation* (CMP, 2020) and/or good facilitation support from an experienced coach.
- This approach may create an "echo chamber" in which a team's erroneous assumptions are confirmed unless there is sufficient peer review and feedback.
- It is important to make sure that the full diversity of different perspectives and stakeholders are included in this work including in particular, braiding together both Western scientific and IK/TK as evidence.
- Given that even this "practical" approach requires a substantial investment of scarce time and resources, it would be important to streamline this approach as much as possible.
- There is a need to dovetail and/or integrate this process with similar existing and proposed agency protocols to minimize confusion and the overall workload.

6 | DISCUSSION AND CONCLUSIONS

The protected area practitioners who took part in the pilot studies found our proposed approach to assess the evidence base underlying their specific conservation strategies both practical and useful for synthesizing the logic of the assumptions and distilling out the known evidence for themselves and their senior managers and decision makers. These practitioners also appreciated that the approach was sufficiently flexible so as to be useful in both relatively simple and more rigorous evidence assessments. This feedback is encouraging because ultimately this approach will only be adopted if its utility in documenting and improving decision-making outweighs the effort required to implement it.

However, it will obviously be important to further test this approach with a wider range of different types of conservation strategies and across different types of organizations with differing levels of capacity to undertake these analyses. The species restoration strategies that were the subject of this work pilot all had similar patterns of questions and assumptions. For example, if a team is looking to restore a species to an ecosystem, then it is important to establish that the major threats that led to

the decline of the species in the first place (e.g., excessive predation on woodland caribou or overfishing of Atlantic salmon) have been sufficiently mitigated before restoration efforts are implemented. It will be interesting to see if analogous patterns could be developed and incorporated into standard templates for other types of conservation strategies. This work could potentially be integrated with the development of generic theories of change for key conservation strategies (Salafsky et al., 2021). In particular, these generic theories of change could include a standard template of the key questions and assumptions that might be required to justify use of a given strategy.

Ultimately, our proposed approach for assessing the evidence base for specific conservation strategies is not meant to be a substitute for the various decision-making frameworks employed by conservation practitioners (Schwartz et al., 2017). Instead, it can be used to assemble and evaluate the evidence needed to implement these frameworks. The key is to develop and assess specific assumptions that support the decision framework. For example, using the *Open Standards for the Practice of Conservation* (CMP, 2020), a team might specify a set of assumptions related to the different potential threats to a conservation target. Or, in a structured decision-making context (Gregory et al., 2012), a team might develop a set of assumptions about the effectiveness and cost of different strategy options, which could then be fed into a consequence table that is used to compare these different options.

To better support this integration with decision-making frameworks, ideally the approach and the Evidence Capture Sheet could be explicitly built into the protocols and tools used to implement these frameworks. For example, there is a current effort to directly integrate this approach into the situation assessment and theory of change diagrams in *Miradi Software*, which is used to support the *Open Standards for the Practice of Conservation*.

Going forward, it will also be important to link these tools to the large body of work being undertaken to synthesize available evidence. From a practitioner's point of view, there would be enormous utility in being able to formulate a specific assumption and then either be given guidance on how to search for synthesized evidence related to this assumption or even to have the system search on their behalf and then provide prompts drawing attention to it. Likewise, from a synthesizer or researcher's point of view, it could be very useful to know what assumptions practitioners are testing and where there are evidence gaps that need to be filled, either by synthesis of existing information, or through postulating forward-looking hypotheses that could be tested by future monitoring and/or research, as shown in the right-hand side of Figure 1 (Dubois et al., 2019; Salafsky & Margoluis, 2021).

On a related note, there is still a great deal of work to be done to ensure that our proposed approach to assessing evidence, which itself was developed within a Western science paradigm, is compatible with Indigenous ways of knowing. This includes enabling and empowering Indigenous community perspectives in defining the key assumptions that are being evaluated, building on the traditions used since time immemorial by Indigenous peoples globally in their management of and interactions with the ecosystems in which they live (Wong et al., 2020). It also means including IK/TK as sources of evidence to assess these assumptions. Within this work, building mutual trust and a method for documenting and advancing IK/TK using principles of Ownership, Control, Access, and Possession (OCAP; First Nations Information Governance Centre, 2015) surrounding the data so that colonial exploitative practices are not repeated, is essential. Learning to braid IK/TK and Western-style scientific knowledge requires the use of ethical space and principles of two-eyed seeing (No'kmaq et al., 2021; Reid et al., 2020) and use of long-established co-management principles (Lee et al., 2021).

In sum, while the approach presented in this study can undoubtedly be refined and improved, it will enable practitioners to develop and assess the evidence base for the critical assumptions that underlie their specific conservation strategies. We hope that it will facilitate better cooperation between researchers who synthesize evidence and practitioners who use evidence to make conservation both more effective and efficient.

CONFLICT OF INTERESTS
The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS
Nick Salafsky, Judy Boshoven, Jaclyn Lucas, and Richard Margoluis led the initial development of the definitions and approach presented in this study. Robyn Irvine, Jean-François Bisaillon, Lalenia Neufeld, and Kent Prior led the pilot tests of this approach with technical expertise on each pilot and refinement of the approach provided by Amanda Lavers, André Y. Laurin, Becky Graham, and Paul Harper. Nick Salafsky and Robyn Irvine led the writing, the discussion among co-authors,

and the submission and publication of the manuscript. All authors extensively discussed and contributed ideas, reviewed and vetted the definitions and approach, and collaborated in reviewing feedback from reviewers and editing various drafts of this manuscript.

DATA AVAILABILITY STATEMENT

All data used to generate this study are presented in the study or the supplemental materials.

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SUPPORTING INFORMATION

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How to cite this article: Salafsky, N., Irvine, R., Boshoven, J., Lucas, J., Prior, K., Bisaillon, J.-F., Graham, B., Harper, P., Laurin, A. Y., Lavers, A., Neufeld, L., & Margoluis, R. (2022). A practical approach to assessing existing evidence for specific conservation strategies. *Conservation Science and Practice*, e12654. https://doi.org/10.1111/csp2.12654