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PERSPECTIVE

Foresight science in conservation: Tools, barriers, and mainstreaming opportunities

Gabrielle Ednie, Tyreen Kapoor, Olga Koppel, Morgan L. Piczak, Jessica L. Reid, Alyssa D. Murdoch, Carly N. Cook, William J. Sutherland, Steven J. Cooke

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Abstract Foresight science is a systematic approach to generate future predictions for planning and management by drawing upon analytical and predictive tools to understand the past and present, while providing insights about the future. To illustrate the application of foresight science in conservation, we present three case studies: identification of emerging risks to conservation, conservation of at-risk species, and aid in the development of management strategies for multiple stressors. We highlight barriers to mainstreaming foresight science in conservation including knowledge accessibility/organization, communication across diverse stakeholders/decision makers, and organizational capacity. Finally, we investigate opportunities for mainstreaming foresight science including continued advocacy to showcase its application, incorporating emerging technologies (i.e., artificial intelligence) to increase capacity/decrease costs, and increasing education/training in foresight science via specialized courses and curricula for trainees and practicing professionals. We argue that failure to mainstream foresight science will hinder the ability to achieve future conservation objectives in the Anthropocene.

Keywords Anthropocene · Decision-making · Environmental planning · Futures research · Strategic foresight

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INTRODUCTION

Scientists, philosophers, and researchers have been trying to predict the future for centuries (Kay 1989; Cobb 2012). Advances in futures research in recent years have led to the creation of a framework based upon the concept of foresight (Martin 1995, 2010; Loveridge 2009), which has been referred to by many terms including strategic foresight (Slaughter 1997), forecasting (Makridakis and Wheelwright 1978), and futures studies or futurology (Flechtheim 1966). Here, we adopt an encompassing definition of foresight science as a systematic approach that draws upon different analytical and predictive tools to understand the past, examine present trends, and provide insight into escalating or newly emerging trends. Further, the foresight science approach draws parallels with the scientific method and ultimately aims to support an evidence-informed action plan that strives towards an identified ideal future (Cook et al. 2014b).

Fields that undergo rapid change, such as technology, economics, agriculture, energy, and policy, frequently use future predictions to aid in present day planning and management (Habegger 2010; Proskuryakova 2017; Butter and Duin 2020; Barrett et al. 2021). For example, imagine if health care professionals could predict if, and when, an individual would have cardiac events so they could intervene beforehand, or if military strategists could identify and avoid future military conflicts. Although it would have been beneficial if the COVID-19 pandemic had been foreseen by a global government, foresight science did contribute to the management of the response with scenario planning by modelling the efficacy of public health measures such as mask wearing or lockdowns (see Gariboldi et al. 2021). Depending on the field and the emerging issues that need to be addressed, a variety of foresight

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science tools can be used, such as horizon scanning, forecasting, scenario planning, and statistical modelling (Lindgren and Bandhold 2003; Pacinelli 2008; Miles et al. 2016). The successful application of foresight science in other disciplines makes it an attractive framework to apply to environmental issues (Calof and Smith 2012; Cook et al. 2014b). Some foresight science tools have been applied in conservation or natural resource management contexts (see Case Studies below). Yet, foresight science as a broader framework has not been widely adopted as demonstrated by the term's infrequency in environmental science literature (Fig. 1). The Web of Science database was searched for articles containing the phrase "foresight science" and the search was refined by the categories Environmental Science. The phrase was found in under ten publications per year until 2010. Publications from 2022 up until March 31 are included.

Today we face escalating biodiversity and climate crises with solutions that may take decades to implement (Ross et al. 2016). Moreover, anthropogenic factors have been shown to change and accelerate natural processes, leading to emerging threats that are difficult to predict and require rapid interventions (Vanderheiden 2006). However, decision-making can be accelerated and aided through foresight science. Foresight science provides an organized framework and supplies tools that can structure complex decision-making processes. Future predictions can also help inform best practices in conservation and other environmental disciplines. Additionally, the application of foresight science allows for decision-makers and scientific practitioners to prepare for both expected and unexpected future conditions by generating and drawing on predictions to inform conservation actions and fostering collaboration with stakeholders (Adams et al. 2018). While foresight science is already being used in some environmental fields, such as climate change (Lelyveld 2019; Muiderman et al. 2020), it is still largely underutilized, particularly in natural resource management and biodiversity conservation.

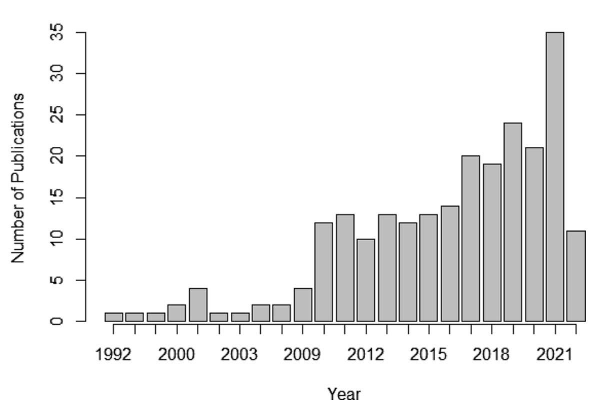


Fig. 1 Number of publications by year from environmental science articles on the Web of Science database containing the phrase "foresight science" in the field of environmental science

In their foundational paper, Cook et al. (2014a) argued that conservation could benefit from forward-looking approaches to decision-making with the strategic use of a comprehensive foresight science toolkit. The framework proposed by Cook et al. (2014a, b) identified six steps: setting the scope, collecting inputs, analyzing signals, interpreting the information, determining how to act, and implementing the outcomes. Key tools for each step within the foresight framework were also outlined. Despite the call from Cook et al. (2014a) for greater adoption of foresight science to support proactive conservation planning, policy, and management, there remain barriers to mainstream use within the environmental field. Indeed, most conservation scientists remain unfamiliar with foresight science as a specific discipline and how it may be used to connect their research findings to more actionable conservation outcomes (Bengston 2019).

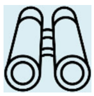
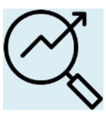
To enable effective decision- and policy-making in the present day and future, we must gain a deeper understanding of the capabilities of foresight science, as well as barriers to mainstreaming. The objectives of our paper are to (1) revisit and update the taxonomy of foresight science tools first outlined by Cook et al. (2014a, b) and their possible application in conservation science, and (2) identify barriers and opportunities for mainstreaming the use of foresight science to address escalating and prospective conservation issues.

We first examine the associated strengths and weaknesses of individual foresight tools within the foresight science framework and provide a contemporary overview of the taxonomy of tools and relevant examples of their application in biodiversity conservation (see Table S1). Next, we highlight three diverse case studies to illustrate how some of the foresight science tools have been successfully applied in conservation science, as well as associated benefits. Then, we highlight barriers that currently prevent more active use of foresight science in conservation. We identify strategies and measures to mainstream foresight science, which aim to build the capacity to overcome associated barriers and generate more actionable conservation science. Our goal is to outline the benefits for scientists, decision-makers, and stakeholders of adopting a more forward-thinking, proactive approach to our current and future conservation problems through the use of foresight science.

CONTEMPORARY OVERVIEW OF TOOLS

The six step foresight science framework (summarized in Table 1 with relevant biodiversity conservation examples)

Table 1 Overview of the foresight science framework consisting of six steps and selected example tools and applications from conservation science literature

Foresight science framework steps		Tool	Definition	Example from ecology, conservation science, or related
	Setting the Scope: *Creating a foundational understanding of the critical issues, key actors, and social, economic, ecological limits of the question*	Stakeholder analysis	Identifies key actors in an issue, who may be the most affected by decisions, for consideration of in decision-making aspects of the project	Brown et al. (2016)
	Collecting Inputs: *Gather information from a wide variety of sources, examine current, past and potential future trends, and identify early indicators of change*	Horizon scanning	The gathering, identifying, and examination of emerging trends, issues, and indicators of change	Neve et al. (2018)
	Analyzing Signals: *Understand the dynamics and drivers of the system being studied to identify problems and develop solutions*	Trend Impact Analysis	Tracking and extrapolating of future trends, guided by expert input, based off the historical data of a given issue	Gädeke et al. (2017)
	Interpreting Signals: *Understand collected information and sources of uncertainty to consider alternative futures and their potential consequences*	Scenario Planning	Identify, create, and explore possible future conditions of a system, and illustrate key events, decisions, and consequences in them	Calvo Robledo et al. (2020)
	Determining How To Act: *Synthesize information to identify concrete actions which will develop indicators of change and promote a desired future outcome*	Backcasting	Highlights a desirable future outcome and moves step-by-step backwards into the present while determining key steps and barriers that might be encountered along the way	Brunner et al. (2016)
	Implementing Outcomes: *Implementation of selected action plans and the subsequent monitoring and modification of strategies*	Adaptive Management	Track environmental change and inform desired states for directed management by constantly monitoring outcomes and reevaluating the needs of the project	Morris et al. (2020)

and associated tools help identify potential future scenarios, weigh their consequences, and explore solutions and mitigating strategies. As new tools are adapted for conservation science from other fields, we encourage current and aspiring scientists and decision-makers to take advantage of developments in other sections. We highlight some of the most applicable tools below (further tools and several biodiversity conservation examples are provided in Table S1).

Setting the scope

The first step in the foresight science framework lays out a fundamental understanding of the critical issues, key actors, and social/economical/ecological limits of the question. This is often achieved using mapping and planning tools such as issues or logic trees, stakeholder analysis, and system maps. Both issue trees and system maps are visual organization tools that identify various aspects of an issue/question and show the relationship between them. Issue trees are systematic modelling tools to quantify different types of uncertainties (Nemeth et al. 2018). In this framework, decisions or uncertainties are expressed as branches of a tree that represent user decisions or variations of outcomes, sometimes beyond one's control (e.g., aspects of environmental hazards; Gerstenberger et al. 2009). Stakeholder analysis is a process that identifies those individuals who will be the most impacted by decisions regarding the emerging issue, to prioritize them for involvement in the decision-making process (Reed et al. 2009). Stakeholder analysis highlights the importance of public participation in various fields of research and how individuals, groups or organizations need to be selected in a way that limits bias and increases the range of perspectives and voices that will inform a given project. Depending on the rationale for the exercise, such as wanting to identify stakeholders or examine relationships between them, a variety of methods can be employed including organizing focus groups, interviews, knowledge mapping, or social network analysis (Reed et al. 2009). Once the key issues have been identified, the relevant information can be collected in the next step.

Collecting inputs

The second step of foresight science focuses on compiling information on the identified issues from a wide variety of sources to examine past and current future trends, as well as to identify early indicators of change (Cook et al. 2014b). Tools that have been previously identified to assist with the collecting inputs stage have included scanning tools (e.g., horizon scanning, see Sutherland and Woodroof (2009); literature reviews, lagging/leading indicators, interviews, and expert workshops; Cook et al. 2014a, b). Specifically, horizon scanning is designed to explore futures by systematically examining information sources to detect early indications of development and change (Hines et al. 2019). Relative to other tools within the foresight science taxonomy, horizon scanning is relatively widespread and has been used for various topics including education, social infrastructures, urbanization, and emerging technologies across the world (Cuhls et al. 2015). Annual horizon scans to identify emerging global conservation issues have been conducted since 2009 (see Sutherland et al. 2022 for the most recent scan). Further application of horizon scanning could be achieved with artificial intelligence, which can systematically open sources of data including search news, social media and web (Bengston 2019). Implementing tools such as horizon scanning to compile relevant information will allow users to proceed to analyze signals in the data.

Analyzing signals

The main goal of the third step is to understand the dynamics and drivers of the system being studied to identify problems and develop solutions. This is done by analyzing data from a variety of past and present sources to explore emerging trends, drivers, system dynamics, and model potential impacts (Cook et al. 2014b). When analyzing signals, foresight science practitioners utilize statistical modelling tools such as trend impact analysis, and cross-impact analysis. These tools can be used to predict potential futures based on historical data, and the models can be used to compare effects of different components on the behaviour of a system and make predictions about alternative actions (Pacinelli 2008). There are approaches in statistical modelling that are widely used in conservation biology, largely due to modern software programs that are relatively affordable and easy to navigate (Pacinelli 2008). However, a shortcoming of some of these statistical modelling approaches is that they extrapolate historical data into the future without consideration for the potential impact of unexpected future variables (Gordon 1994; Pacinelli 2008). Trend impact analysis is a tool that addresses this shortcoming by allowing additional factors that may be present in the future to be included in models and adjusting the extrapolation (Glenn and Gordon 2009). Lastly, cross-impact analysis is another modelling tool that uses probabilities to understand how one event impacts the likelihood of other future events (Cook et al. 2014b). Once issues and solutions have been identified using trend impact analysis and cross-impact analysis, options for actions to implement can be developed in the next step, interpreting information.

Interpreting information

The fourth step in the foresight science process involves drawing conclusions, making inferences from the data gathered, and seeking agreement on the potential pathways forward. One tool conservation biology can benefit from implementing is scenario planning. Scenario planning is the process in which potential future conditions are identified, and their potential consequences and key events are explored. The suite possibilities can be overwhelmingly large, but the ability to identify early indicators of a potential future is an invaluable benefit of this tool. Another tool appropriate for conservation biology is the

Delphi method, as well as its modernized online counterpart, eDelphi (Gordon 1994; Van der Duin 2016). Originally developed for military applications in the 1950s, the Delphi method captures a range of diverse perspectives from stakeholders and subject matter experts through several rounds of surveys in order to inform possible ways to act (Van der Duin 2016). The futures wheel is another widely used tool in interpreting information in which a user may visualize the direct and indirect consequences of a decision, change, or trend (Cook et al. 2014b). The futures wheel was recently recognized for its potential value in decision-making and planning in the real estate field (Toivonen 2020). There is a modern update, the Implications Wheel developed by futurist Joel Barker (https://www.implicationswheel.com/), which shows both long and short-term potential implications resulting from a decision or change. Once options for actionable steps are identified through tools such as scenario planning, the Delphi method and the futures wheel tool, action plans can be established in the next step.

Determining how to act

The fifth step of foresight science synthesizes information from the previous steps to generate concrete recommendations. The creation of effective action plans may require many tools outlined in part by Cook et al. (2014a), including backcasting, roadmaps, risk analysis, fifth scenario, reverse engineering, and decision modelling. Producing multiple action plans is essential when preparing for uncertain future conditions. Tools such as AI-assisted decision modelling and backcasting integrate biological, social, and economic considerations. Employing an AI-assisted decision modelling tool could accelerate the process and, with proper development, remove potential biases in the decision-making process (Scoville et al. 2021). However, as a relatively new tool, there is still the need for consideration of ethical issues. Furthermore, it is likely this approach will still require human assistance to input training data and learn decision-making pathways, which may lead to the entrenchment of the training data or programmer's biases into the software. For example, misclassification errors could wrongfully identify local community members as poachers, raising potentially severe legal and safety concerns, and eroding trust in AI-based approaches to environmental problems (Wearn et al. 2019). Human bias in training data or lack of understanding of the implicit assumptions of an algorithm could also result in a rare species being overlooked in environmental impact assessments and a subsequent loss of its habitat due to development (Wearn et al. 2019). To minimize these biases, conservation groups (e.g., government, non-government, community-led organizations) could benefit from using backcasting (highlighting a desirable future outcome and by moving step-by-step backwards into the present while determining key steps and barriers that might be encountered along the way) in parallel with AI-assisted decision modelling to identify missing steps and barriers to the AI-generated decisions (Gordon 1994). Backcasting has already been used successfully in the context of endangered woodland conservation in Australia (Gordon 1994). Once action plans are created, they can be implemented and monitored for results in the next step, implementing outcomes.

Implementing outcomes

The final step in the foresight science framework is the implementation and subsequent monitoring and modification of the chosen action plan (Cook et al. 2014b). Adaptive management is a strategic process that involves weighing different management outcomes to inform future management success (Cook et al. 2014b). Other fields, such as education, cite the successful implementation of adaptive management in ecology as an example to follow (Serrouya et al. 2019; Hecht and Crowley 2020; Lynch et al. 2021). This is perhaps a rare case in the context of foresight science where other fields can learn how to monitor complex systems from environmental science. Adaptive management allows for the tracking of environmental change and inform desired states for directed management by constantly monitoring outcomes and reevaluating the needs of the project (Morris et al. 2020; Lynch et al. 2021). This growing realization seemingly led to its rise in environmental fields. This tool was effectively used in Ontario's Long-term Soil Productivity approach (Morris et al. 2020). It was also useful to aid in the recovery of the endangered woodland caribou across an expansive landscape (Serrouya et al. 2019), which was achieved by assessing which management strategy was most effective at increasing caribou populations, and subsequently informing future conservation groups on such best practices. Once action plans are implemented and adaptive management practices are put in place, the project will have reached its conclusions and continuously improved to prevent or mitigate negative future outcomes.

BENEFITS FOR CONSERVATION SCIENCE: CASE STUDIES

Biodiversity conservation in South Africa

A case study on South African biodiversity and conservation incorporated specific steps of the foresight science framework using horizon scanning and the Delphi method to identify emerging and intensifying issues over the next 5–10 years in the region (Seymour et al. 2020). After horizon scanning identified key problems and opportunities, they were subsequently prioritized using the Delphi method to inform future actions. The issues identified were grouped into common themes including disaster-oriented management (i.e., triaging as opposed to proactive protection of biodiversity), increased land-use changes (mostly for agriculture purposes), foreign global development goals, domestication of wildlife (for the game industry, resulting in decreased ecosystem function), and decreased engagement with nature via shifts to urban lifestyles (Seymour et al. 2020). Though some of these issues are extremely complex and 'wicked problems' (Rittel and Webber 1973), this horizon scan represents a crucial step in determining which common themes require additional scientific evidence and analysis. The authors suggested that the way forward would be to undertake strategic scenario planning exercises to formulate interventions, responses, or management strategies to address these anticipated challenges.

Population viability analysis for Ontario turtles

Population viability analysis (PVA) identifies influencing factors on the future viability and probability of extinction for a given species (Boyce 1992). Today, PVA is used to describe both the analysis and set of tools used to create timeline scenarios and understand factors driving the extinction of species. For example, Midwood et al. (2015) conducted PVAs on bycatch mortality of threatened freshwater turtle species in Ontario, Canada. The study determined that even low levels of female mortalities caused by bycatch in small-scale commercial fisheries could lead to a future scenario of the extirpation of four turtle species within the next 50 years (Midwood et al. 2015). Since then, turtle bycatch mitigation strategies have been integrated into Ontario hoop-net fisheries through collaborations between researchers, resource managers, and industry (Larocque et al. 2020). In 2013, the Ontario Commercial Fishers Voluntary Biodiversity Protocol was put forth which promoted industry implementation of bycatch reduction devices. Follow-up monitoring of turtle status led to a change in the protocol from voluntary to mandatory in 2019, demonstrating the use of adaptive management (Larocque et al. 2020). PVA can be a powerful tool for conservation biologists to estimate a species' sensitivity towards future conditions and identify best practices to better inform management objectives and recovery plans.

Managing aquatic ecosystems and water resources under multiple stress (MARS) initiatives in Europe

The recently completed European Union initiative entitled *Managing aquatic ecosystems and water resources under multiple stress* (MARS; http://www.mars-project.eu/) hosts many examples of projects that used scenario planning and forecasting tools to examine multiple stressors in European fresh waters (Baattrup-Pedersen et al. 2018; Couture et al. 2018; Stefanidis et al. 2018; Molina-Navarro et al. 2020; see http://www.mars-project.eu/index.php/publications.html for more examples). First, future storylines examining the years 2030–2060 were developed with stakeholder input to include variables such as climate change, greenhouse gas emissions, land-use change, and various socioeconomic factors (Sanchez et al. 2018). Three storylines were selected, each with a different focus from governments prioritizing economic growth over environmental protection (Storyline 1), balanced growth between people and technology (Storyline 2), and a disjointed future, where fossil fuels are prioritized over environmental and water management strategies (Storyline 3; Sanchez et al. 2018). Following this scenario planning, a MARS-funded study by Molina-Navarro et al. (2020) used these three storylines to model the future environmental quality of the Odense Fjord basin in Denmark and the Sorraia basin in Portugal. Using Bayesian Belief Networks to examine both biological and physical indicators of change, authors found that biological indicators of ecosystem health (e.g., macroinvertebrates and fishes) did not deviate largely from current conditions in the forecasted storylines for the Odense basin. In the Sorraia basin, biological indicators, specifically fish, are expected to decline based on the effects of climate change and flow regime changes in the region. By examining ecological responses to forecasted storylines, evidence-based management alongside research recommendations can be developed and invested in for the specific needs of each basin to support better futures for people and nature.

BARRIERS AND OPPORTUNITIES FOR MAINSTREAMING

Given the benefits and utility of foresight science we consider the barriers and opportunities for mainstreaming foresight science in conservation. Opportunities for mainstreaming lie mainly in our ability to overcome the identified barriers. We hope that by doing so, the mainstreaming of foresight science will follow naturally.

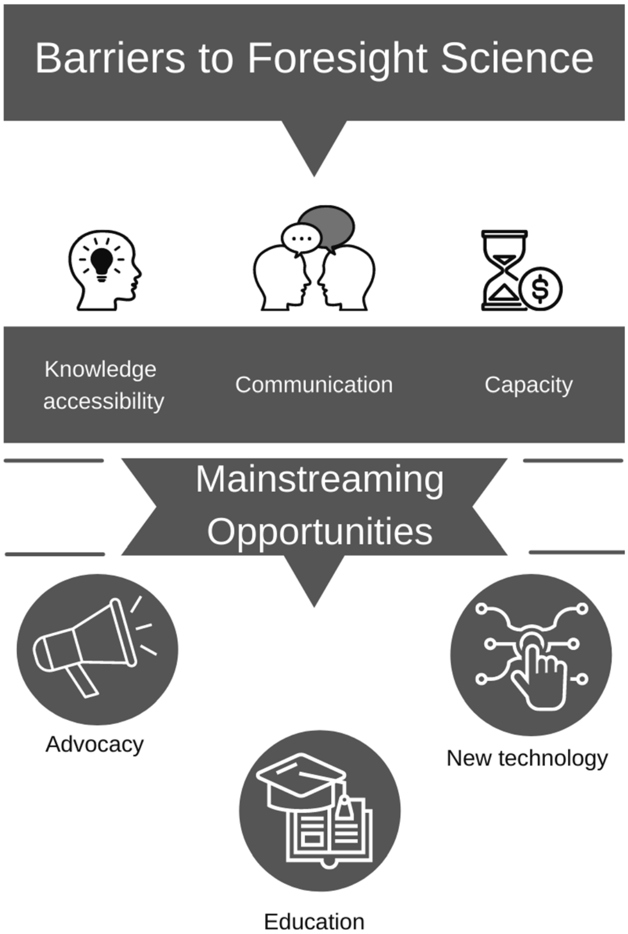


Fig. 2 Identified barriers to the application of foresight science in conservation and opportunities for mainstreaming

Barriers

As a framework built of many separate tools, foresight science has multiple obstacles to overcome before it can be mainstreamed. These barriers can effectively be summarized into three categories: knowledge accessibility, communication, and capacity (Fig. 2). Conservation science is mostly discussed in academia, specialized governmental agencies, and a variety of non-governmental agencies (da Fonseca 2003). While each likely has the same barriers, the effects of each barrier will be relative to the power and resources of each establishment.

While there exists a large quantity of scientific knowledge, data are spread across multiple platforms and is often inaccessible (Jeschke et al. 2019). In conservation science, large amounts of data are typically required to produce models and make predictions. Additionally, barriers to accessing these data to inform conservation decisions can include inaccessible government databases and interfaces or the 'file drawer problem' (Kennedy 2004) whereby useful information or data can become lost or stored physically (rather than digitally; Piczak et al. 2022). Ensuring all relevant data have been collected and is accessible becomes difficult. This creates a distinct barrier as the quality of the data input directly influences the quality of the tool outputs and the efficiency of the foresight science framework. When modelling future trends and possibilities, accessing or acquiring the knowledge needed to systematically quantify uncertainties is an important barrier (Scherbaum and Kuehn 2011). More importantly, current knowledge transfers between academic circles and decision-makers have largely been ineffective, which creates disconnects between what scientific knowledge dictates and which policies are enacted (Lavis et al. 2003; Bertuol-Garcia et al. 2018a; Mitchell and Laycock 2019).

Perhaps the most complex barrier to foresight science is the lack of communication between conservation agencies, stakeholders, and decision-makers. Lack of proper communication with identified stakeholders can be very harmful for the efficiency of the foresight science framework, as stakeholder participation is a crucial part of the process. Miller et al. (2020) identified inadequate communication, lack of evidence-informed decisions, lack of trust, and power imbalances as common themes in preventing stakeholder engagement for marine conservation in Australia. Further, social network analyses have revealed that within management systems of conservation programs there was a disconnect in terms of communication amongst the involved NGOs (Nita et al. 2018). Stakeholder input and participation makes the framework outputs more inclusive and successful (Bautista et al. 2017). The key is to encourage and build capacity for collaborative science, as diverse involvement will balance creating projects that are evidence-informed and equitable (Gould et al. 2018). Early inclusion and communication with stakeholders and other groups can contribute to a more robust, diverse, and inclusive decision-making process. Typically, communications with stakeholders are done through workshops and interviews. However, this can be challenging when they are in remote regions or rendered impossible by global pandemics. In conservation science, research and policy decisions are often made by separate organizations. This creates a disconnect that drives inefficiencies in the decision-making process (Bertuol-Garcia et al. 2018b; Mitchell and Laycock 2019). Action plans produced by researchers for issues they have identified are often wasted as researchers do not have the support of an organization with power to make actionable decisions. Therefore, it becomes a challenge to advocate for the use of tools that produce action plans, such as backcasting and AI-assisted decision making, to those who do not have the power to act on the results.

The most prevalent and best-known barrier to the foresight science framework may be the lack of capacity (Legg and Nagy 2006; Kermorvant et al. 2019; Miller et al. 2020), which includes a lack of temporal and monetary investments as well as expertise (Kermorvant et al. 2019). Long-term monitoring is a crucial process in foresight science but scientists and practitioners often lack the capacity, specifically funding, to follow up on projects. This limits the ability to adopt an adaptive management approach (sensu McLain and Lee 1996) as it is difficult to adjust questions or adapt to changing conditions while lacking critical data to inform these decisions. Decision-making and mapping exercises like trees and system maps have the potential to become large, overwhelming, and complex. Other tools, such as trend impact analysis, require expertise and knowledge of statistical modelling, which can create barriers in expertise acquisition (Pacinelli 2008). Adopting stakeholder analysis practices in future projects also requires a level of expertise and previous experience. Miller et al. (2020) also identified inadequate capacity as a common theme in preventing stakeholder engagement for marine conservation in Australia. Other foresight tools, while already increasing in popularity in conservation sciences, face barriers to their integration as a default management tools for conservation practitioners. In the case of adaptive management, constant monitoring for effective adaptive management requires substantial temporal and monetary investments that most organizations do not have access to (Kermorvant et al. 2019). As a result, optimizing cost-efficiency of long-term monitoring, through design or technological improvements, is a frequent topic in scientific literature (Legg and Nagy 2006; Linchant et al. 2015; Kermorvant et al. 2019). Long-term monitoring requires a stable qualified workforce, research equipment, field technicians, and substantial funds that most organizations cannot or will not invest (Legg and Nagy 2006). This is also the case for novel foresight tools that require advanced technology, such as artificial intelligence. Large investments are required to obtain the technology and train a qualified workforce; a resource not easily accessible to each establishment.

Currently, not enough time is spent considering and investing in future risks (Calof and Smith 2012). Most efforts are centered around solving current issues that need immediate solutions. One of the biggest strengths of foresight science is its ability to anticipate and potentially prevent future issues by implementing actions that change current trajectories to improve the future. Using the framework solely to solve immediate issues is wasted potential; more time needs to be spent acting on future issues based on future conditions (Kerr 2020). The increasing conservation crises and weather events caused by climate change might be better handled with effective use of foresight. This call to action is perhaps best summarized by the S20 report, which outlines the primary conclusions of the 2020 Science 20, representing the National Academies of Science of G20 nations: *Foresight research has the potential to propel the science community into a needed central role to develop deeper, more accurate, and more comprehensive foresight methods to drive effective policy making. There is a need for foresight research that can connect the dots, allowing the assessment of the impact and unintended consequences of decision options and leading to visionary actions at an international level.*

Mainstreaming opportunities

Foresight science is already becoming more mainstream with the emergence of establishments such as Policy Horizons Canada, which uses foresight to help plan policies, discussions centered around foresight in reputable conferences such as S20, and specialized peer reviewed journals such as "Futures & Foresight Science". Such platforms help legitimize and circulate information about the framework. Some tools have also been mainstreamed independently of the foresight science framework, such as adaptive management, which is frequently used in conservation practices. However, the strength of the foresight science framework lies in its ability to use many tools in conjunction to produce more well-rounded and accurate projects which lead to effective conservation practices (Cook et al. 2014b). The key to mainstreaming foresight science lies in overcoming the outlined barriers. As with most things, ease of use encourages popularity. We propose that the three main opportunities for mainstreaming foresight science are: advocacy, emerging technologies, and education (Fig. 2).

Advocating for foresight science is the first mainstreaming opportunity and can involve new ways of articulating the importance of the foresight science framework and tools to solve conservation problems (van Kerkhoff et al. 2019). The need to improve communication between researchers and decision-makers is a long-standing challenge. Improving relationships between the two groups may require change on an institutional level. Most decision-makers reside in governmental agencies, where new systems are slow to be implemented. As a rapidly evolving field, new foresight science tools are constantly being developed. Constant advocacy for adoption of foresight science tools and the foresight science framework remains the best way to communicate with decision-makers and ensure they are using the best tools available to solve important conservation issues. Advocacy can come in the form of opinion pieces, petitions, lobbying, letter writing campaigns, etc. Another opportunity for addressing the communication barrier is taking advantage of an interdisciplinary approach to problem-solving. This is especially important when initiating conservation projects in post-colonial societies including many countries across Africa and South America, as well as settler states such as the United States, Canada, and Australia. Some Indigenous communities operate in their own forward-thinking approach by "looking seven generations ahead" (Borrows 2008). As foresight science tools and making well-informed predictions often also depend on the past, Indigenous knowledge and values regarding the history of species or ecosystems would only enhance the Western framework of foresight science, if collaborations are mutually beneficial, respectful, and co-produced. For example, a foresight science approach has been recently applied to invasive plant management in Australia to assess the impacts on both environmental and Indigenous cultural values (Adams et al. 2018).

Technological advances are the second opportunity for mainstreaming as all communication barriers cannot be overcome through advocacy. An interesting advancement regarding tools for scoping and collecting input that has occurred during the COVID-19 pandemic has been the transition of meetings and engagements from in person to online platforms. Tools identified by Cook et al. (2014a) for collecting inputs including workshops and interviews, which previously would have likely occurred in person, could benefit from an online platform in that there may be an associated increase in frequency of communications. While the COVID-19 pandemic has significantly altered many aspects of human life, associated changes in behaviour including increased use of online platforms (Karl et al. 2022) could potentially contribute to the mainstreaming of foresight science. Online communication can also decrease cost in terms of time commitment and financial resources, especially when interacting with stakeholders in remote communities (Cook et al. 2014a). Nevertheless, online platforms may simultaneously make it harder to build relationships with stakeholders, as not everyone has equal access to the internet and communication devices (Kadykalo et al. 2022).

Many new tools and technologies outlined above, such as AI and online communication, have the potential to greatly reduce the time and effort required and, therefore, increase capacity. AI can automate data collection, model future trends, and assist in decision modelling (Kuziemski and Misuraca 2020; Scoville et al. 2021), which saves time. Automating data collection might simultaneously help overcome knowledge accessibility barriers by creating pathways that automatically scour all available online data (Hines et al. 2019). However, a general lack of data might lead to biases and blind spots in the AI's decision making. For example, recommendations for smart farming innovations often fail to account for limitations food producers face daily as these may be unique to each farmer and the information may not be available publicly (Fraser 2022). Nevertheless, AI has the potential to save a lot of time, increase efficiency, and reduce the workforce required to complete some of the more complex steps of foresight science, while still providing useful information and recommendations that can be disseminated to the appropriate local authorities and managers. Increasing technological capacity would greatly improve the ability of conservation agencies to effectively utilize the adaptive management tool. Furthermore, technological advancements are constantly introducing new technologies, which can increase the efficiency of environmental research and monitoring. Drones have been quickly incorporated into wildlife monitoring as can be both time and cost effective (Linchant et al. 2015). Such technologies can help increase the capacity of conservation agencies to complete long-term monitoring of their projects. We note, however, that operating drones may not always be safe or possible depending on the region of study's legislature and social-political climate. Nevertheless, the growing digital divide on the national and international levels may prolong the mainstreaming of such tools. Even in North America and Europe, not every individual or establishment has the means or the ability to use such technology.

The third way to overcome barriers is proper training and education on the use of the foresight science framework. In most countries, government agencies and non-governmental environmental organizations are those with the power, time, money, and expertise to use it effectively (da Fonseca 2003). To ensure these agencies have the skills to employ such tools, current and future environmental professionals must be trained in their usage. Every tool requires a different level of knowledge and expertise. Some can be taught quickly, while others require years of training to be completed effectively. For practicing environmental professionals, specialized workshops could be created for professional development purposes (Slaughter 2004). For future environmental professionals, specialized foresight science courses could be incorporated in college and university curricula (Goldbeck and Waters 2014). While it is not necessary to use every tool in the foresight science framework to complete a successful foresight science study or to apply foresight in practice, having a working knowledge of most of the tools would increase awareness of the best tools available to solve the issues at hand. A quick scan of key textbooks in conservation science (e.g., Primack 1995, 2006; Sodhi and Ehrlich 2010; Sher 2022) reveals little emphasis or content on foresight science aside from PVA. Availability of well-trained foresight science experts will increase the capacity of establishments to utilize foresight science tools, increase the efficiency of each tool, and advocate the use of the framework. Having individuals at every level of academia or industry who are knowledgeable in the intricacies of the entire framework would go a long way in ensuring its use permeates entire establishments and effectively becomes mainstreamed.

Lastly, the best way to mainstream foresight science is to enforce accountability of project completion. Many conservation projects are abandoned at the implementation phase (Jarvis et al. 2020). Instilling a system of accountability, especially towards stakeholders, decision-makers, and politicians, as is the case in the United Kingdom (UK), would improve follow-through and encourage action-driven research (Habegger 2010). While the UK boasts many examples of foresight tool implementation (Habegger 2010), each country has unique government structures and policy contexts that may either help or hinder the incorporation of foresight tools, especially in conservation science. This presents unique barriers that are too complex to account for in the present generalized study. However, conservation practitioners and managers are encouraged to take into account their local political climates when forming their foresight science implementation strategy. As this framework aims to prevent future issues, there is not much social pressure to prioritize these projects. However, these tools are invaluable, and their worth will be revealed over time as long as we follow-through with projects and take action.

CONCLUSION

We foresee a future where foresight science is embraced and widely used by environmental professionals and relevant organizations (e.g., government natural resource management agencies, industry, non-governmental organizations). The irony in that statement is intentional in that as of now foresight science has not been mainstreamed, yet it is impossible to know with certainty if that vision will be achieved. We argue that failure to achieve that vision will constrain the ability to deliver conservation success for the Anthropocene (Williams et al. 2020). There are many conservation issues and challenges today along with currently unanticipated and emerging issues on the horizon. Conservation science operates on a long timescale (Cvitanovic et al. 2021), especially when it comes to activities such as the recovery of endangered species (Foin et al. 1998) and the restoration of ecosystems (Willis and Birks 2006; Willis et al. 2007). Being able to look to the future in terms of understanding threats and responses to different interventions has the potential to make conservation science more sound and decisions more effective. We call on the conservation science and practice community to increase education to learn what foresight science has to offer, enforce accountability of project completion, and to apply the foresight science framework to the pressing issues of today and tomorrow. Predicting the future will always be imperfect (Von Schomberg et al. 2017) but failing to try puts biodiversity and ecosystem health at even more risk and impedes evidence-informed conservation.

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Declarations

Competing interests The authors declare that they have no competing interests.

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AUTHOR BIOGRAPHIES

Gabrielle Ednie (✉) is a M.Sc. student at the University of Ottawa, Canada, with interests in microclimate ecology and remote sensing advancements.
Address: Biology Department, University of Ottawa, 75 Laurier Ave. E, Ottawa, ON K1N 6N5, Canada.
e-mail: gab.ednie@gmail.com

Tyreen Kapoor is a M.Sc. student at Carleton University, Canada, with an interdisciplinary research interest in knowledge exchange practices for science-policy development.
Address: Biology Department, Carleton University, Ottawa, ON K1S 5B6, Canada.
e-mail: tyreen.kapoor@gmail.com

Olga Koppel is a Ph.D. Candidate at the University of Ottawa, Canada, with a research interest in global change biology and pollinator conservation.
Address: Biology Department, University of Ottawa, 75 Laurier Ave. E, Ottawa, ON K1N 6N5, Canada.
e-mail: o.a.koppel@gmail.com

Morgan L. Piczak is a Ph.D. Candidate at Carleton University, Canada, with an interest in spatial ecology, restoration ecology and conservation science.
Address: Biology Department, Carleton University, Ottawa, ON K1S 5B6, Canada.
e-mail: morganpiczak@gmail.com

Jessica L. Reid is a M.Sc. student at Carleton University, Canada, with a broad research interest in aquatic sciences, specifically in freshwater fishes, macroinvertebrates, and habitat restoration efforts.
Address: Biology Department, Carleton University, Ottawa, ON K1S 5B6, Canada.
e-mail: jessicaareid17@gmail.com

Alyssa D. Murdoch is a Mitacs Postdoctoral Fellow with the Department of Biology at Carleton University and Wildlife Conservation Society Canada, with an interest in the impact of multiple stressors on northern fishes.
Address: Biology Department, Carleton University, Ottawa, ON K1S 5B6, Canada.
Address: Wildlife Conservation Society Canada, 169 Titanium Way, Whitehorse, YK Y1A 0E9, Canada.
e-mail: alyssamurdoch@gmail.com

Carly N. Cook is a Senior Lecturer in Conservation Biology and DECRA Fellow in the School of Biological Sciences at Monash University in Melbourne, Australia, with an interest in the integration of science in environmental management decisions.
Address: School of Biological Sciences, Monash University, Melbourne, VIC 3800, Australia.
e-mail: carly.cook@monash.edu

William J. Sutherland is a Miriam Rothschild Professor of Conservation Biology in the Department of Zoology at the University of Cambridge, UK, with an interest in conservation science and decision-making processes.
Address: Department of Zoology, University of Cambridge, The David Attenborough Building, Pembroke Street, Cambridge CB2 3QZ, UK.
Address: Biosecurity Research Initiative at St Catharine's (BioRISC), St Catharine's College, University of Cambridge, Cambridge CB2 1RL, UK.
e-mail: w.sutherland@zoo.cam.ac.uk

Steven J. Cooke is a Professor (Former Canada Research Chair) in the Department of Biology and Institute of Environmental and Interdisciplinary Sciences at Carleton University, Canada, with an interest in integrative biology, conservation science, and natural resource management.
Address: Biology Department, Carleton University, Ottawa, ON K1S 5B6, Canada.
Address: Institute of Environmental and Interdisciplinary Sciences, Carleton University, Ottawa, ON K1S 5B6, Canada.
e-mail: Steven.Cooke@carleton.ca