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Data, politics, and funding cause uncertainty for conservation practitioners

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Abstract

Choosing management actions to protect biodiversity requires decisiveness amidst complexity. To identify barriers to effective conservation, we asked over 150 conservation practitioners working with the Canadian federal and provincial/territorial governments, non-government organizations, and private industry about their experience with uncertainty when making decisions. Using inductive thematic coding, we identified that "data," "resources", and "governance" ranked as the most significant sources of uncertainty for respondents. Practitioners also proposed solutions that would reduce their uncertainty, which included improved funding processes, better collaboration, changes to governance processes, and the use of data and evidence in decision-making. Conservation practitioners consistently mentioned elements of uncertainty that exist outside of their immediate control, indicating that substantial uncertainty in conservation decision-making occurs due to broader dynamics in governance and society.

KEYWORDS

biodiversity conservation, biological data, Canada, evidence, management actions, political uncertainty

1 | INTRODUCTION

Effective conservation requires that practitioners working on the ground have tools to make sound decisions in the face of immense complexity. Conservation decisions can take numerous forms, including deciding which species should be listed as at risk, where and how to allocate land for protection, which management approaches to use, and designing follow-up monitoring (McCarthy, 2014; Possingham et al., 2001). While these decisions may appear straightforward, practitioners tasked with this work are expected to make choices at the interface of ecological, social, and economic influences while facing considerable uncertainty.

Robust evidence is key to making conservation decisions (Sutherland et al., 2004) and its availability can change the course of conservation outcomes (Walsh et al., 2015). In conservation, most approaches focus on

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managing epistemic or knowledge uncertainties, defined as uncertainties associated with the (lack of) knowledge or understanding of natural systems, such as measurement errors, natural variations in populations, inherent randomness in complex systems, and model uncertainty (Ascough et al., 2008; McCarthy, 2014; Regan et al., 2002). Epistemic uncertainties are often managed and accounted for through quantitative approaches (e.g., more data collection, modeling, Value of Information or info-gap theory) that support decision analysis (Ben-Halm, 2023; Bolam et al., 2018; Keith et al., 2011; McCarthy, 2014; Wyborn et al., 2016). However, the lack of access for practitioners to scientific literature can make using the most up-to-date evidence difficult (Fuller et al., 2014; Shanley & López, 2009) and, even when accessible, scientific evidence may not be applicable in conservation practice (Lemieux et al., 2021). Instead, many practitioners rely on experience (Cook et al., 2010) and past management approaches to guide their decisions (e.g., management plans, policies) which may also lack robust evaluations of their effectiveness (Pullin et al., 2004). This compounds uncertainty around best management practices or policies.

Other sources of uncertainty have also been identified in the literature, including linguistic or conceptual uncertainty (which refers to the vagueness and ambiguity that can emerge in scientific vocabulary and symbolic dimensions where there may be divergent understandings), societal decision-making (including goals/targets, policies and management practices), assessment and performance measures, and normative assumptions that are tied to social acceptability and public consent (Ascough et al., 2008; Haila & Henle, 2014; Regan et al., 2002), Much uncertainty in conservation decision-making also arises from socio-economic sources, and viewing conservation science and practice as a social process embedded in broader dynamics is necessary to address the complex problems that give rise to contemporary conservation crises (Sandbrook et al., 2013). This is further demonstrated by the expansion of conservation social sciences (e.g., Bennett et al., 2017; Massarella et al., 2021). Conservation practitioners must deal with socio-economic sources of uncertainty, including funding constraints (Nyboer et al., 2021; Pollard et al., 2019), organizational mandates (Weber et al., 2019), and internal organizational challenges (Lemieux et al., 2018; Nguyen et al., 2019), which can affect conservation processes and outcomes. Beyond funding, the cost of conservation action itself (e.g., variations in the cost to purchase land for protection) can be uncertain and complicate decision-making by making trade-offs and returns on investment unclear (Carwardine et al., 2010). Studies have found that political and economic considerations are often top-of-mind for decision-makers, with uncertainty stemming from not knowing how influential parties such as stakeholders and rightsholders will respond to conservation decisions (e.g., Young et al., 2016; Young et al., 2018).

Uncertainty has been identified as a major barrier in conservation (Rose et al., 2018), and while approaches exist to quantify epistemic uncertainty and its influence on management decisions (e.g., Bennett et al., 2018), there is a gap around which sources of uncertainty are most relevant to practitioners, both in individual projects (Runge et al., 2011) and more generally. In this study, we surveyed Canadian conservation practitioners about their experience of uncertainty when making conservation decisions. Our goals were to better understand decision-making uncertainty experienced by conservation practitioners, and to identify pathways for managing—and when possible, reducing—this uncertainty to improve conservation outcomes. Due to Canada's layered governance structure, legacy of colonialism, the role of private and public sectors in conservation and its national commitments to reversing biodiversity decline, the uncertainty in conservation decision-making experienced by Canadian practitioners can be immense (Cooke et al., 2016). Canada is also an excellent case study for other jurisdictions, such as USA and Australia, which have analogous governance structures and histories of colonialism. To provide actionable solutions to managing uncertainty, we also asked practitioners what actions or changes could reduce their uncertainty when making decisions.

2 | METHODS

Our practitioner survey (provided in the Tables S1–S7) was administered from December 10, 2022, to May 1, 2023, using Qualtrics© software (Provo, UT; https://www.qualtrics.com). The survey received ethics clearance from Carleton University's Research Ethics Board on December 6, 2022, and was offered in French and English. Respondents remained anonymous but had to be over 18 and currently work with a conservation agency in Canada. "Conservation agency" was defined as any organization doing conservation work and included, but was not limited to, government agencies, non-government organizations (NGOs), and private companies. Recruitment simultaneously used directed, broadcast, and snowball methods which resulted in a non-probability sample. We developed a list of conservation organizations using the expertise of our author team and sent survey invitations to these organizations. We also shared recruitment materials on social media on

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LinkedIn and Twitter (now X). All recruitment materials asked potential respondents to share the invitation within their network to recruit more survey respondents. No compensation was given to respondents for participation.

Our survey used a questionnaire with mixed open- and close-ended questions designed to identify sources of uncertainty, the respondent's decision-making environment, their perception of the prevalence and impact of uncertainty, and solutions to this uncertainty. *Certainty* was defined as being "confident something is known well enough to justify an action" and *uncertainty* was defined as being "not confident something is known well enough to justify an action". *Conservation decision-making* was defined as the "process of choosing a management action that aims to sustain, enhance, or otherwise positively impact biodiversity conservation".

To analyze sources of uncertainty, the first question (Q1) in the questionnaire asked respondents to identify the major sources of uncertainty they experience when making decisions about conservation in a professional capacity, with a prompt indicating that uncertainty can come from "multiple sources, such as the natural world or social and political processes." Respondents then had five open-ended text boxes where they could enter their sources of uncertainty and rank them from 1 (most significant source) to 5 (least significant). We chose a five-point scale to balance choice and simplicity. Respondents did not have to provide five sources of uncertainty. Other questions throughout the questionnaire allowed us to understand conservation decision-making experienced by practitioners. Respondents used Likert scales to rate their level of decision-making autonomy, perceptions of decision-making in their current work environment, and their perception of the prevalence and impact of predetermined sources of uncertainty on their decision-making. These predetermined sources of uncertainty (the environment, teammates or colleagues, stakeholders or rightsholders, funding, evidence, elected leaders, agency or organization leaders) were developed collaboratively by leveraging the expertise from the author team, which includes conservation ecologists, conservation social scientists and conservation practitioners. Governance structures, collaborations with stakeholders, and differing priorities and values among elected leaders and stakeholders are known common challenges to conservation decision-making (Hemming et al., 2022). These sources of uncertainty also align with the literature on uncertainties in conservation. While most studies focus on epistemic uncertainty (e.g., data, evidence and the environment; Regan et al., 2002; McCarthy, 2014), the literature recognizes social and economic sources of uncertainty (e.g., the impacts of colleagues, stakeholders and leaders, funding; Haila & Henle, 2014; Ascough et al., 2008; Sandbrook et al., 2013; Pollard et al., 2019; Carwardine et al., 2010). Our approach was also informed by the study of social-ecological systems, which recognizes that governance systems and social interactions contribute to shaping environmental systems (McGinnis & Ostrom, 2014). To identify pathways for managing sources of uncertainty, a second open-ended question (Q7) asked respondents "Which actions or changes would reduce the degree of uncertainty you experience in your conservation decision-making process?"

We analyzed the two open-ended questionnaire questions responses (Q1 and Q7) using inductive thematic coding to identify emerging codes and themes (Braun & Clarke, 2006; Nowell et al., 2017). Patterns and key themes were identified by leveraging the social-ecological expertise of the author team, acknowledging the importance of social dimensions in conservation as well as sources of uncertainties in conservation identified in the literature such as data and evidence, governance and decision-making, public support and funding (e.g., Ascough et al., 2008; Haila & Henle, 2014; Pollard et al., 2019; Regan et al., 2002). We used this approach to identify the emergent patterns and organize them in overarching themes, though both questions were coded independently. The analytical approach for both questions consisted of three rounds: (1) the first round of analysis involved closely reading all questionnaire responses to Q1 and Q7 and identifying similar elements among the answers; (2) the second round of analysis consisted of grouping similar elements into distinct codes with defined parameters and coding the responses, and (3) the final round involved grouping these emergent codes into broader overarching themes (Saldaña, 2013). Three authors (CR, JV, CB) were involved with the inductive coding to increase reliability of the analysis and final codes (Elliott, 2018). For the first open-ended question (Q1), one author (CR) conducted steps 1 and 2 of the analysis and developed a preliminary codebook, while another author (CB) reviewed the codebook, advised on codes and thematic groupings to finalize the codebook, and a third author (JV) coded a subset of the data using this codebook until there was 100% agreement between coders to ensure consistency and accuracy of the codes (see SM2 for Q1 codebook). Step 3, developing the overarching themes for the Q1 codes, was conducted through discussions among CR, CB, JV, VN, NY and JB. For the second open-ended question (Q7), CR did a preliminary read-through of the answers (step 1) and CB collaborated on the distinct code development and identifying overarching themes. All coding was then completed by CR. Any disagreements in coding for both questions were resolved through intra-group discussions among the

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three authors responsible for coding. An open-ended response could be assigned multiple codes, though an effort was made to be as parsimonious as possible. For example, one respondent noted that a source of uncertainty was "personnel and experience are challenging to coordinate"—this response fell under the theme "Resources" and was coded as both "Personnel" and "Expertise". If same code was mentioned multiple times in an answer, the code was only recorded once.

3 | RESULTS

In total, there were 410 respondents (387 English, 23 French). Of this total, 230 (217 English and 13 French) were "blanks" (i.e., consented to participate in the survey then did not answer any questions), 31 (30 English, 1 French) were drop-outs (i.e., respondent gave some valuable information but did not complete the survey), 4 (4 English) were skips (i.e., respondent mostly completed the survey but skipped a few questions), and 145 (136 English, 9 French) completed the entire survey.

Respondents worked in non-government agencies ($n = 46$), provincial/territorial government agencies ($n = 31$), federal government agencies ($n = 31$), conservation authorities ($n = 22$), industry/private companies ($n = 9$), municipal agencies ($n = 2$), Indigenous governments ($n = 1$), and other ($n = 9$), which included respondents who make conservation decisions as volunteers with arms-length government committees, independent council positions, or positions that straddle jurisdictions. Respondents were responsible for a wide variety of conservation decisions in their professional roles, with involvement ranging from policy development to on-the-ground actions. Examples included land securement, protected areas planning, identifying critical habitat/areas of natural heritage significance for protection, ecosystem restoration, managing human-wildlife conflicts, harvest management (e.g., elk, deer, fish), drinking water protection, invasive species management, species at risk assessments (i.e., status assessments, threat assessments, developing recovery strategies), environmental assessments, permitting, and mitigations/compensation of environmental impacts, and outreach and engagement. Most of the respondents (62% or 93/150) had worked at their current organization for five or more years (Figure 1). Respondents also conducted conservation work in every province and territory in Canada (respondents could select more than one location). Most respondents conducted their conservation work in Ontario, Alberta, British Columbia, and Saskatchewan (Figure 1).

3.1 | Sources of uncertainty

In total, 708 responses were coded for the major sources of uncertainty (Q1; Rank 1; $n = 181$, Rank 2; $n = 172$, Rank 3; $n = 158$, Rank 4; $n = 120$, Rank 5; $n = 77$). Seven overarching themes emerged from this exercise, encompassing the major sources of uncertainty that conservation practitioners experienced when making decisions. Of these seven themes, "data," "resources" and

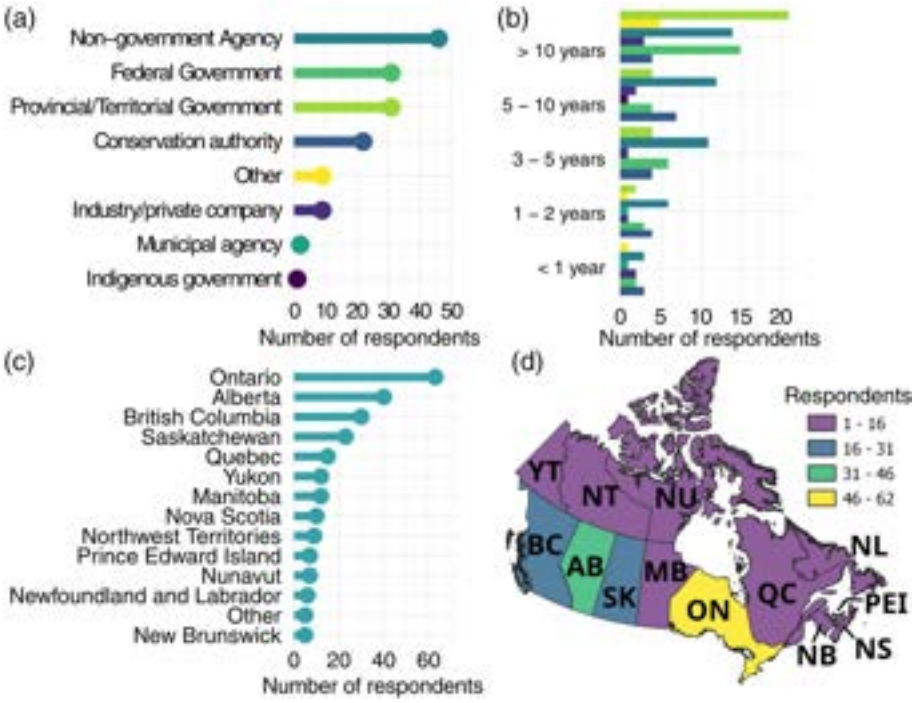

FIGURE 1 Types of organizations for which survey respondents worked (a); the length of time respondents have been working at their respective conservation organization (b); and the number of respondents conducting conservation work in different provinces and territories (c, d). Respondents could select more than one location.

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TABLE 1 Themes identified in responses to the open-ended question "what are the major sources of uncertainty you experience?" when making a conservation decision.

Themes	Description	Count
Data	The creation of or availability of information and knowledge on a subject, including that which may be insufficient, unavailable, or lacking	160
Resources	Assets or supplies, including finances, organizational capacity, personnel (e.g., the number of employees/volunteers), time, and expertise on a topic	129
Governance	Processes that structure the function of an organization and/or determine processes, goals, or outcomes (e.g., politics, legislation/policy, Indigenous rights, internal support)	127
Evidence	Guidance on the application of existing knowledge and information, or knowledge of an intervention or management strategy to inform conservation actions and decisions	106
Public support	Assistance from people external to the organization and its partners, including private landowners (e.g., granting land access), or public perception of conservation actions	60
Social complexity	Interactions among individuals, organizations, and systems (e.g., socio-political-economic systems, gaps or overlaps in responsibilities, communication or collaboration, trade-off assessments, costs, and justice/equity)	59
Ecological Complexity	Interactions among all biotic and abiotic components of ecosystems including the inherent complexity of a changing world	51

Note: Respondents could report up to five sources of uncertainty and answers could contain more than one theme. Counts represent the number of times the theme was mentioned in an answer.

"governance" ranked as the first, second, and third greatest sources of uncertainty for conservation practitioners in Canada (Table 1 and Figure 2). To examine whether certain types of uncertainty were more common among different organizations, we categorized first-ranked sources of uncertainty to the respondent's workplace (Table 2). Only the first-ranked source of uncertainty was used as it had the highest response rate compared to the second through fifth rankings.

The theme "Data" was the most often mentioned source of uncertainty (Figure 2 and Table 1) and focuses on the need to create or improve access to knowledge and information. Responses included codes that captured the need for species-specific information (e.g., "Paucity or absence of local data on species population numbers" [Respondent ID 22544]), long-term datasets which included the history or a baseline of a site, information about potential impacts or specific methods, and 'data' in general (e.g., "Insufficient data to resolve key questions in the decision-making process" [ID 35430]) (see Data S1 for additional detail). Respondents working in federal or provincial/territorial government agencies most often ranked "data" as their number one source of uncertainty (Table 2). Respondents working in provincial or territorial governments who ranked data as their first source of uncertainty were most often working in Alberta ($n = 4$), Ontario ($n = 2$), Saskatchewan ($n = 2$) or Yukon ($n = 2$).

The theme "Resources" was dominated by answers about funding and financial resources (60% of all responses within the theme) (Figure 2 and Table 1). Financial resources included general funding, funding amounts, funding timing and length, or the availability of funds to complete projects (e.g., "Funding opportunities are competitive and often insufficient" [ID 32595] and "Even when [funding is] approved it doesn't always show up in a timely manner" [UID 73782]). Other sources of uncertainty around resources included capacity, timelines, and expertise (e.g., "Lack of internal capacity to accomplish goals" [ID 35284]). Respondents working in non-government agencies most often ranked "resources" as their number one source of uncertainty (Table 2).

Most responses in the "Governance" theme mentioned politics (57% of answers) (Figure 2 and Table 1). This included political will and government priorities, political decision-making, political choices and influence, politics conflicting with conservation and political decisions not accounting for evidence. Examples of responses included how there is a "constantly changing political landscape and priorities" (ID 20896) and how "political interference with legislation and policies" (ID 28368) increased conservation practitioner uncertainty. Sources of uncertainty in governance also encompassed legislation and policy, which included existing legislation, unclear regulatory requirements, uncertainty around interpretation and policies including evidence or science (e.g., "Policy scope missing the scientifically relevant parameters" [ID 31167] and "Policy interpretation by multiple agencies" [ID 59343]). Governance also included "internal support" such as organizational uncertainty, co-management, and administration or hierarchy and Indigenous rights, including consultation, engagement frameworks, consent, and working with First Nations, Inuit and Métis communities (e.g., "Lack of ethical framework and approach for co-governance with Indigenous communities" [ID 86932] and "Political reconciliation versus natural needs... how can the little remaining [land] be provided for reconciliation with First Nations without set

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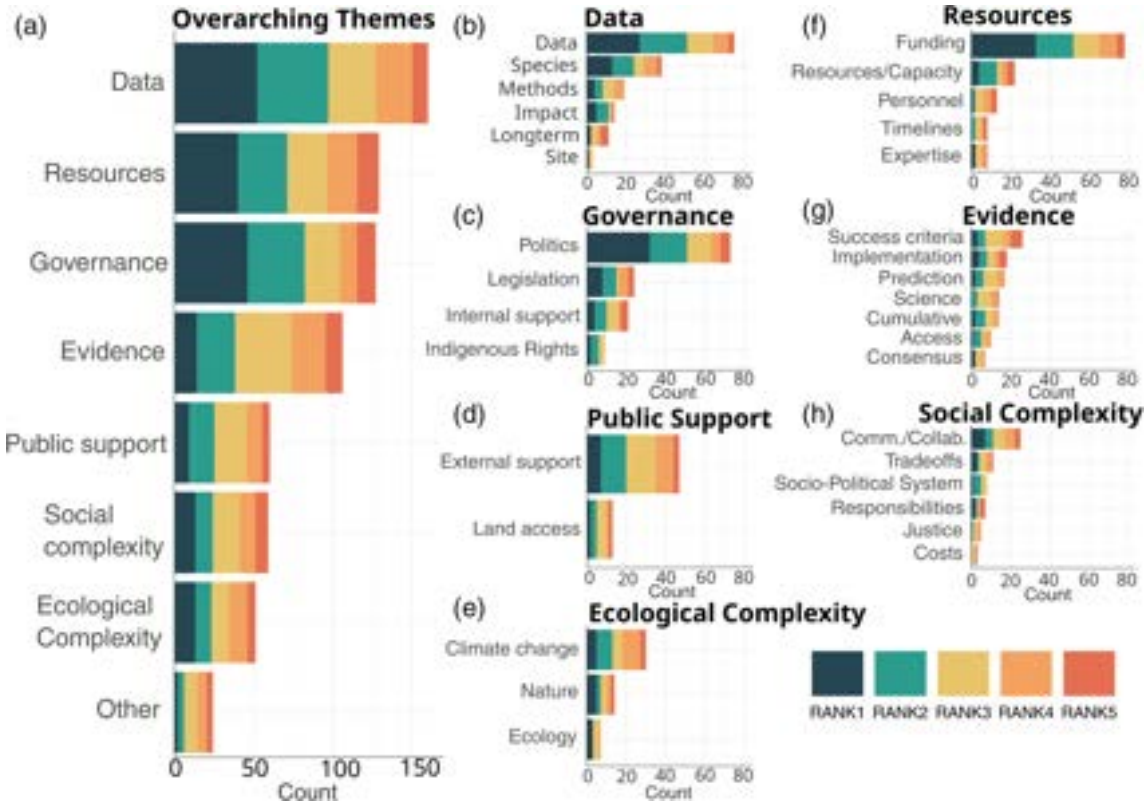

FIGURE 2 Ranked sources of uncertainty from "most significant (1)" to "least significant (5)". Seven overarching themes that emerged (a) are presented with distinct subthemes (b) in descending order of number of mentions.

TABLE 2 First-ranked sources of uncertainty based on the workplace of respondents.

	Resources	Data	Evidence	Ecological complexity	Governance	Social complexity	Internal support	Other
Canadian federal government agency	5	16	4	1	2	0	1	0
Canadian provincial or territorial government agency	0	12	1	2	11	3	2	0
Conservation authority	5	3	0	1	11	0	0	1
Industry/private company	2	2	3	1	2	1	0	0
Municipal agency	1	0	0	0	1	0	0	0
Non-government agency	18	6	3	2	6	8	3	0
Indigenous government	0	0	0	0	0	1	0	0
Other	2	5	1	0	1	0	0	0

asides for conservation?" [ID 94815]). Governance was ranked as the number one source of uncertainty most often by respondents working in Ontario's conservation authorities and provincial/territorial government agencies (Table 2). Respondents working in provincial or territorial governments who ranked governance as their first source of uncertainty were most often working in Alberta ($n = 10$) or Saskatchewan ($n = 6$).

The overarching theme of "Evidence", which we defined as the application of existing knowledge and information to inform conservation actions and decisions, included responses that highlighted access to knowledge, information or data, expert consensus, methods, cumulative or synergistic effects on a landscape, prediction and modeling and metrics of success (e.g., "When knowledge from hunting/fishing guides directly competes with scientific ideas" [ID 83892] and "Lack of a clear document that I can point to, to reference scientific proof in layman terms for my non-academic colleagues" [ID 83892]) (Figure 2 and Table 1).

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The theme of "public support" included the ability to access land, stakeholder support, public and community perceptions, and media coverage (Figure 2). The theme "ecological complexity" included climate change, weather impacting work, and the overarching complexity of nature. The theme "social complexity" included social systems and the complexity of human and natural interactions, responsibilities (e.g., where policy, legislation, mandates make it unclear who is responsible for certain parts of conservation and gaps in responsibility), communication and collaboration (e.g., "Cooperation between" competing "conservation organizations and individuals" [ID 19400]), trade-offs including risk assessments, costs including return on investments, and justice and social movements (e.g., "What are the socio-political implications of this choice" [ID 69273] and "Inconsistent direction coupled with jurisdictional overlap between federal and provincial governments make it difficult to work consistently across the country for federal-scale organizations" [ID 76624]).

3.2 | Practitioner decision-making autonomy and perceptions

Respondents ranked their decision-making autonomy between 1 ("no autonomy—not involved in the decision-making process") and 5 ("full autonomy—can make decisions without permission or approval"). Most respondents ranked their autonomy as 3, the middle of the scale (68/157 or 43%) or slightly higher as 4 (48/157 or 31%); see Supporting Information for details. Fewer respondents ranked their autonomy as 2 (27/157 or 17%), 1 (7/157 or 5%), or 5 (7/157 or 5%).

Respondents felt most uncertain when making long-term decisions (>3 years), with 66% (101/154) of respondents indicating they experience uncertainty on long-term decisions most of the time or always, compared to 35% (54/154) of respondents who indicated they felt uncertain most of the time or always when making short-term decisions (≤3 years). Respondents experienced marginally more uncertainty about making decisions with people outside their organization compared to making decisions with people from within their organization (see Table S4 for detailed responses).

3.3 | Perceived prevalence and impact of uncertainty

To assess the prevalence of uncertainty on decision-making, we asked respondents to think about a typical conservation decision they make as a professional and indicate how *often* they experience different types of uncertainty. A total of 155 respondents answered the question "I experience uncertainty when considering..." using the Likert scale Always, Most of the time, About half of the time, Sometimes, and Never (Figure 3). Elected leaders (96/155 or 62% reported 'always' or 'most of the time') and funding (92/155 or 59% reported 'always' or 'most of the time') were most often perceived to be sources of uncertainty compared to other sources (Figure 3 and Data S1). In contrast, practitioners did not often experience uncertainty when considering the actions or decisions of their colleagues/teammates or their organizational leadership.

A total of 153 respondents answered the question "The following sources of uncertainty impact my decisions..." (Figure 3). The perceived impact of all sources of uncertainty was generally quite high (Figure 3 and Data S1). Uncertainties that were perceived to have the most impact are also the ones that are reported as being the most frequently experienced (e.g., funding, elected leaders). Evidence, funding, and the actions or decisions of elected leaders had the highest proportions of respondents who agreed or strongly agreed that they impacted their decision making. The actions or decisions of teammates and colleagues had the lowest impact on respondents' decision-making, but these were still considerable as 50% of respondents noted that they agreed or strongly agreed that these impacted their decisions.

3.4 | Managing or reducing the experience of uncertainty

Responses to the open-ended question "What actions or changes would reduce the degree of uncertainty you experience in your decision-making process?" yielded eight overarching themes (Table 3 and Figure 4). Select responses for each code are presented in the Data S1. In total, 152 respondents answered this question. "Resources" were mentioned most often and were heavily focused on funding. Respondents suggested that improved funding processes (e.g., "clear funding objectives"), better access to funding (e.g., "Increased access to funding opportunities"), and increased and more long-term funding would alleviate uncertainty. Respondents also suggested that increased access or the creation of data and evidence would help with uncertainty (e.g., "Higher degree of collaboration to create high-quality datasets that are standard" and "More general data over larger areas and longer time frames, as opposed to really great data on a single species in a localized area"), as would using data and evidence more broadly (e.g., "Evidence-based decision-making at senior,

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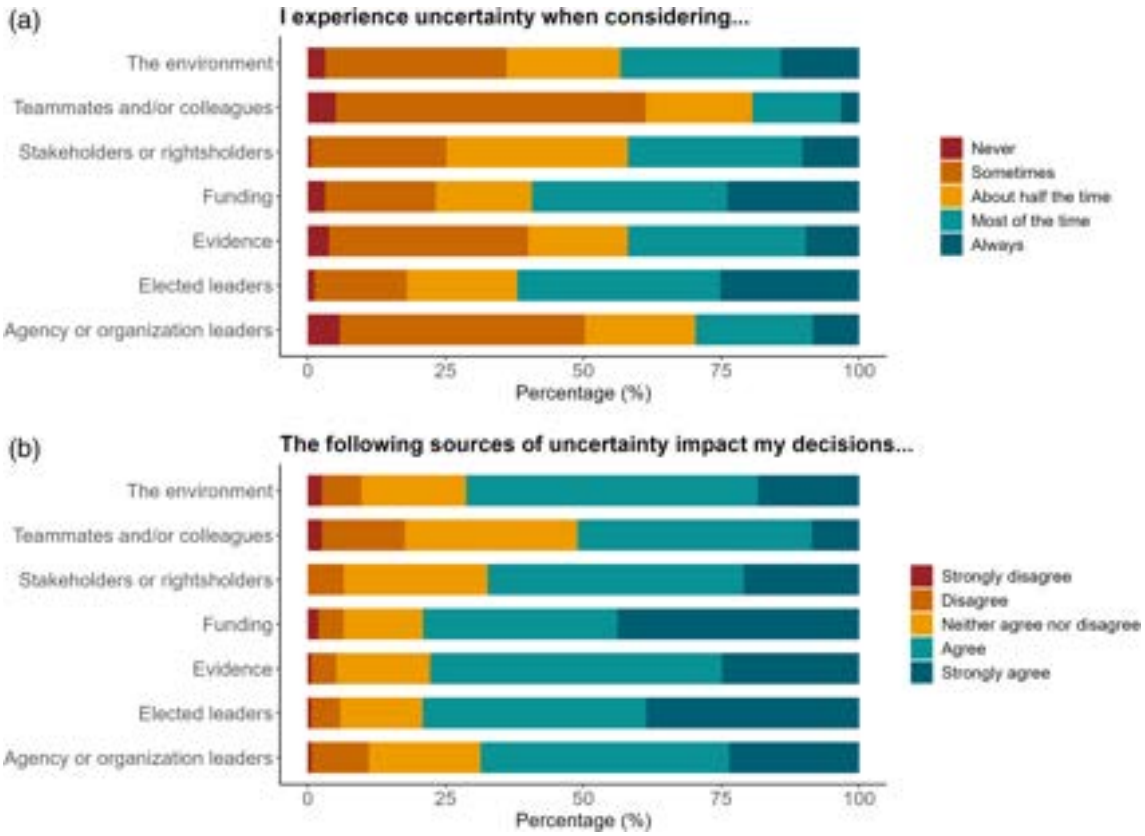

FIGURE 3 Responses of practitioners, when asked to consider a typical conservation decision, how often they experience identified sources of uncertainty (a) and how these sources of uncertainty impact their decisions (b).

political, and intergovernmental levels.") and acceptance and documentation of uncertainty in favor of action (e.g., "... document where the uncertainty exists" and "Parties learn to understand compelling evidence versus reliance on an overly precautious application of the precautionary principle by not doing anything.").

Practitioners also noted that clearer priorities (e.g., "clearly communicated conservation goals") along with longer-term actions, clear timelines, stable government priorities, and stronger policies (e.g., "Strengthening of policy framework and Provincial support for Conservation Authorities.") would reduce their uncertainty. Another overarching theme for reducing uncertainty was the quality of governance processes, which included transparent decision-making, reduced political influence (e.g., "Little to no influence of current political powers and public opinion"), accountability and support, and more autonomy and empowerment for conservation practitioners (e.g., "Autonomy under a defined budget; a clear decision-making process that outlines where my autonomy extends."). Practitioners also expressed desire for more collaboration and engagement, particularly improved public engagement/education, better processes for collaboration (e.g., "More support and capacity for co-management bodies/community organizations and Indigenous governments.") and better internal and external communication (e.g., "More cross sector data sharing and communication."). Some practitioners also suggested external factors that would reduce their uncertainty, including new technological developments and major socio-economic changes.

4 | DISCUSSION

Choosing management actions that sustain, enhance, or positively impact biodiversity requires decisiveness in the face of complex systems and vast uncertainties. While data was indeed identified as a major source of uncertainty, resources and governance were also ranked highly by respondents. In turn, practitioners reported that their uncertainty could be reduced by decidedly interconnected solutions, including access to resources, clear priorities, quality of governance processes, collaboration and engagement, and access to and use of data and evidence. To better understand the decision-making context experienced by conservation practitioners, we discuss sources of uncertainty and practitioner suggestions for managing them.

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TABLE 3 Themes regarding measures to reduce uncertainty and the number of responses from conservation practitioners that contained each theme (answers could contain more than one theme).

Theme	Description	Count
Resources	Provision of the materials and support necessary to do work, including funding processes, finances, and capacity.	81
Priorities	Clarity about what is considered important by organizations, governments, and society, including long-term actions, timelines, stable government or policies, meaningful climate action, and social and political will.	45
Data and evidence	Access to or creation of knowledge and information, including standardized datasets, collaborative data creation, or evidence synthesis to guide management.	43
Use of data and evidence	Improvements to how existing data, science, or knowledge are used in the decision-making process, including evidence-based decision-making, addressing biases in data collection and evaluation, improved documentation of uncertainty and evaluations of outcomes.	35
Quality of governance process	Improvements to the processes that govern conservation decision-making, including greater transparency, reduced political oversight/influence, clarity around policies and legislation, better support, clear jurisdictions and more autonomy and empowerment.	40
Collaboration and engagement	Enhanced abilities to work with people, organizations, governments and communities, including improved public engagement or education, processes, science-politic collaboration, and better internal and external communication/collaboration.	38
External factors	Improved tools and paradigm shifts for factors external to the conservation practitioner's role, including the development of new technology and socio-political revolutions.	2

4.1 | Data as a source of uncertainty

'Data' was the most frequently reported source of uncertainty when making conservation decisions. Examples of specific needs included information on species population numbers and overcoming poorly characterized baseline conditions. This aligns with the literature on uncertainties in conservation, which has a large focus on epistemic sources of uncertainty including errors in data, natural variations and randomness in systems, and uncertainties in modeling and in data interpretation (Ascough et al., 2008; Regan et al., 2002) that can result in insufficient data. Management decisions are also intertwined with epistemic uncertainty, as the amount of survey effort in an area, the areas set aside for conservation, and the resources invested in conservation efforts can influence how much is known about the state of a system (McCarthy, 2014).

Many conservation decisions in Canada are reliant upon high-quality data, as exemplified by the designation of "at risk" greatly favoring species with more available information (Lukey et al., 2010). However, robust data is often not readily accessible for practitioners, nor used by them if it is available (Cook et al., 2010; Cooke et al., 2021). Several reasons have been identified for this "knowing-doing gap" (Hulme, 2014). Scientific publications that may contain useful information are often inaccessible to practitioners via paywalls (Roche et al. 2022) or they are written such that management implications are opaque, or methods are difficult to grasp for non-specialists (Cooke et al., 2021; Hulme, 2014). Often, robust scientific information to solve a conservation problem simply does not exist. For example, research on the ability to detect occurrences is apparently nonexistent for 94% of threatened and endangered species in USA and 87% of threatened and endangered species in Canada (Bennett et al., 2024). Many practitioners thus depend on personal experience on the ground (Cook et al., 2010).

These issues have long been recognized, and there is hope that they can be at least partly addressed. Many granting agencies now require that papers resulting from grants are open access in some form (e.g., "accepted" but unformatted versions; Tri-Agency Canada, 2015). Research outlets are also increasingly encouraging the use of lay summaries and graphical abstracts, to ease interpretation. In addition, new data repositories such as the Open Science Framework (https://osf.io/) are allowing researchers to publicly archive and share their data. Specialized, curated and accessible evidence syntheses are also emerging. For example, the Conservation Evidence Database (https://www.conservationevidence.com/) provides simple graphical summaries of the effectiveness of conservation actions and more detailed synopses of the evidence contained in published studies.

4.2 | Governance and politics as a source of uncertainty

Governance—the processes that structure the function of an organization and/or determine processes, goals, or

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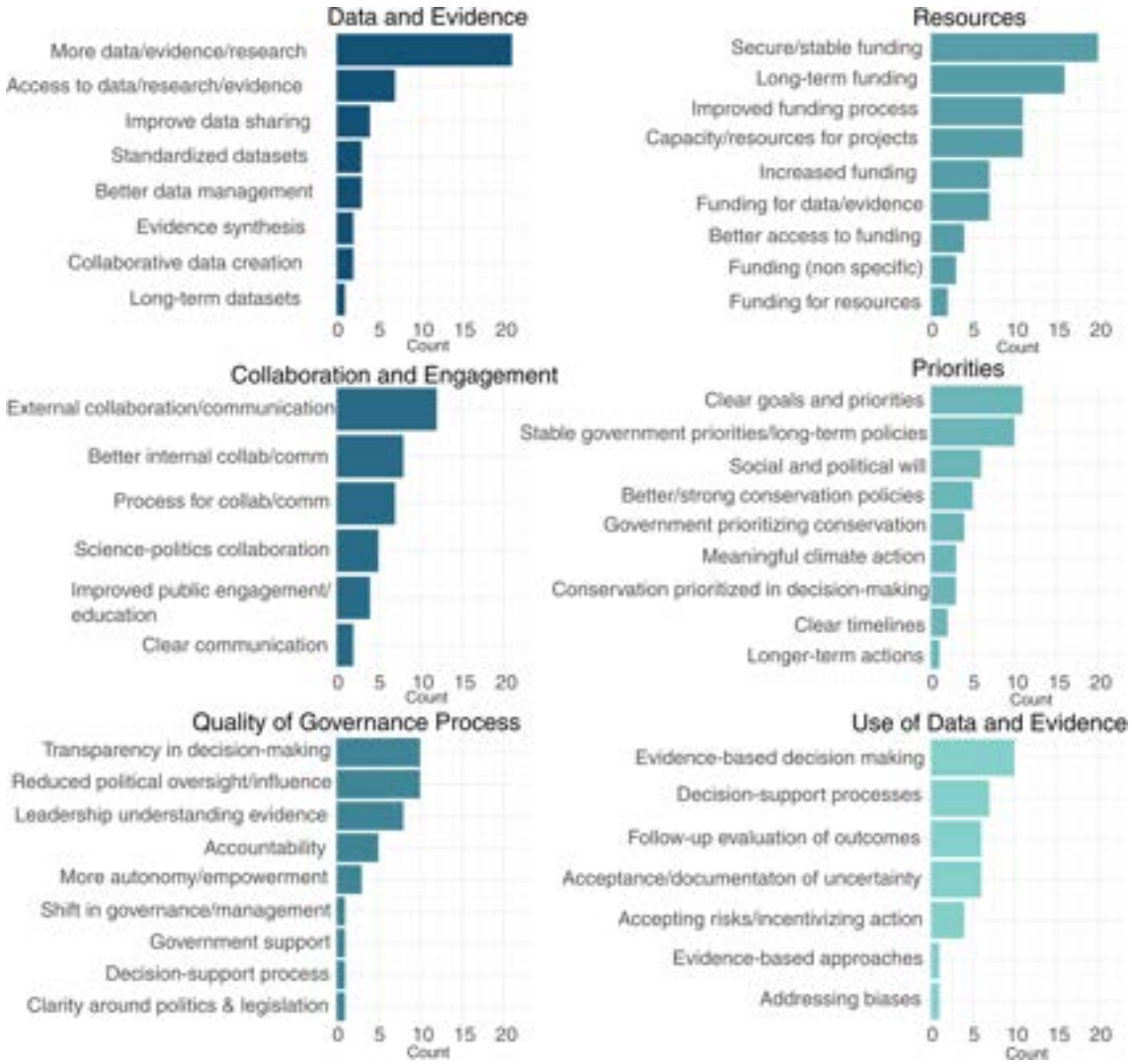

FIGURE 4 Respondent answers to the question "What actions or changes would reduce the degree of uncertainty you experience in your conservation decision-making process?" Respondent answers could contain more than one code or theme.

outcomes (e.g., politics, legislation/policy, Indigenous rights, internal support)—was mentioned second most often as the most significant source of uncertainty. This aligns with previous findings that identify societal decision-making (e.g., goals/targets, policies, management, assessment and performance measures; Ascough et al., 2008; Regan et al., 2002) as well as normative assumptions, social acceptability and public consent (Haila & Henle, 2014) as sources of uncertainty. Practitioners identified constantly changing political landscapes and associated priority changes as impeding their ability to make decisions. A considerable number of respondents also named concerns about biases and direct political interference, including biases and policies undermining environmental protection. Environmental policies in North America are increasingly polarized or tied to electoral politics (i.e., Botchwey & Cunningham, 2021; Dufresne & Ouellet, 2019; Pepermans & Maeseele, 2016). Canadian politics have a legacy of affecting the environment, from the rollbacks and obstructionism under the Harper Conservatives (e.g., Lakanen, 2018; Turner, 2013; Wellstead, 2018) to the prominence of environmental issues under the Trudeau Liberals (Botchwey & Cunningham, 2021), followed by recent rollbacks of many initiatives. Within our survey, there were 22 participants from conservation authorities in Ontario, half of which cited "governance" as their number once source of uncertainty. Conservation authorities, established by the province in 1946 and governed under the *Conservation Authorities Act* (Government of Ontario, 1990), provide integrated management at the watershed level, an approach that has received praise for its adherence to natural systems rather than artificially created political boundaries (e.g., Mitchell et al., 2014; Shrubsole, 1996). However, since 2019 the Ontario provincial government has been introducing legislation to dramatically weaken conservation authorities (Mitchell et al., 2021; Syed, 2019) resulting in limited powers and reduced mandates (Syed, 2024) which benefit development.

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This politicization of conservation authorities and the rapid, politically motived mandate changes negatively impacted respondents working at conservation authorities in Ontario and impinged on their ability to make meaningful conservation decisions.

Concerns about governance extended to decisions being made based on opinion or fear, rather than evidence, and legislation or policies that miss scientific evidence, vague regulatory expectations, and inconsistent interpretations of regulations, policies and legislation. Environmental governance in Canada exists in a conflicted space between attempting to preserve "wilderness" while also extracting natural resources for capital gain (Lakanen, 2018). This can lead to environmental management approaches, such as impact assessments, being ineffective at halting environmental destruction (e.g., Murray et al., 2018) or legal frameworks failing to achieve conservation outcomes (e.g., Ray et al., 2021; Swerdfager & Olive, 2023). If the mandates of conservation agencies are driven by capitalism, their ability to conserve the environment can be weakened. For example, employees may face difficulty publicly identifying the causes of environmental degradation (Rogers, 2021), the destruction of habitat may be allowed by accepting payments into an "offset" fund (e.g., Bethlenfalvy & Olive, 2021), and settler-colonial dynamics may be reinforced, despite outward commitments to Indigenous-led conservation (Youdelis et al., 2021). These situations produce considerable uncertainty for practitioners who must make decisions in the best interests of the environment while existing within this system. Practitioner suggestions to improve the quality of governance processes included transparency in decision-making, reduced political influence or oversight, more autonomy, clarity around policies, legislation, and jurisdiction, and accountability to commitments for leadership.

4.3 | Funding and resources as causes of uncertainty

Resources—defined here as assets or supplies, including finances, organizational capacity, personnel, time, and expertise—were the third most prominent source of uncertainty for respondents, with answers overwhelmingly mentioning funding. The literature has previously demonstrated that practitioners face funding constraints (Nyboer et al., 2021; Pollard et al., 2019) as well as uncertainty around the cost of conservation actions (Carwardine et al., 2010). Practitioners noted that various aspects of funding increased their uncertainty, including funding opportunities that are competitive and insufficient, funding not arriving in a timely manner, a lack of long-term or secure funding, and no funding for follow-up or evaluations of project outcomes. These results correspond with previous analysis suggesting that biodiversity conservation in Canada is underfunded by $15–20 billion USD per year (Kosciolek et al., 2020). Proposed actions to reduce funding uncertainty included clear funding objectives, better access to funding opportunities, longer terms and increased amounts of funding, and funding for specific conservation objectives such as gathering data, developing planning tools, and project resources (e.g., staffing). These results align well with Nyboer et al.'s (2021) survey of senior Canadian federal/provincial government and NGO managers in environmental fields, which suggested changes to funding models that included supporting co-production and interdisciplinary research with longer grant durations and conducting impact evaluations to follow up on research outcomes.

The actions that practitioners suggested would reduce their uncertainty emphasized the interconnected nature of conservation work in Canada. While increased access to resources was the most often mentioned solution, practitioners connected this to clearer organizational, government, and societal priorities surrounding conservation, knowledge generation, the quality of governance processes, the use of data and evidence in decision-making, and improving opportunities for collaboration and engagement. Institutional structures are often perceived by practitioners as barriers to incorporating new knowledge into decision-making practices, including lack of political will, lack of internal support, and funding issues (Nguyen et al., 2019).

4.4 | Evidence as a source of uncertainty

In recent years there have been demonstrable declines in the use of evidence by practitioners making decisions about protected areas in Canada (Lemieux et al., 2021). In fact, decision-makers and practitioners need to balance the need to support decisions with evidence and the need to act despite epistemic uncertainty (e.g., if there are long delays to obtain evidence; Cook et al., 2013). Recommended solutions to these declines included ensuring scientific research has practical relevance, increasing collaborative knowledge-sharing, embedding and empowering scientists and knowledge holders in organizations, and increasing accountability and transparency of ecological data and information (Lemieux et al., 2021). Despite our survey targeting a wider range of conservation practitioners, the solutions for reducing uncertainty that practitioners provided parallel these suggestions. This indicates that improvements to

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conservation practice have solutions that, at their core, are broadly applicable across organizations, disciplines, and roles.

4.5 | Accepting uncertainty

Some practitioners noted that uncertainty cannot be significantly reduced and instead should be well-documented and accepted as part of the decision-making process. The inability to manage or accept uncertainty can have negative consequences on conservation outcomes (Buxton et al., 2020). For example, low information availability was associated with a higher frequency of not assigning species to a risk category by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) rather than following the precautionary protocol and designating the species despite data deficiencies (Lukey et al., 2010). By quantifying and documenting uncertainty, conservation decision-makers can incorporate it into predicted outcomes, increase transparency, and more thoroughly evaluate the options available to them. Documenting uncertainty also ensures decision-makers are appropriately confident and understand the limitations of current knowledge or practices. Codifying decision support processes into organizations can help practitioners manage and document sources of uncertainty (Hemming et al., 2022) while making the best decisions with the resources currently available to them. Linking uncertainty directly with decisions can also help identify which sources of uncertainty have the greatest potential impact on decisions, so their reduction can be targeted (Runge et al., 2011). Some uncertainty will remain irreducible, at least in the timeframes that matter for biodiversity conservation. In many cases, it is much more important to act in the face of some uncertainty than to wait for more information, risking a lost opportunity (Martin et al., 2012). Adaptive management, an approach that embraces uncertainty, both values knowledge but also recognizes the need to act despite outstanding uncertainty, while opening up the possibility to adapt as new data and experiences build over time (Wyborn et al., 2016). Adaptive management emphasizes that policy commitments should be adaptive and should account and test for different alternative scenarios and solutions (Keith et al., 2011).

4.6 | Settler-colonialism as a source of uncertainty

The tension of colonization and conservation arose as a source of uncertainty from survey participants. Canadian conservation must continue to reckon with its history of colonization, and the legacy of colonialism that still influences conservation and land management today. The Canadian concept of conservation is rooted in hierarchy, exploitation, and extraction—ideas that separate humans from land (Johnson & Murton, 2007; Mansuy et al., 2023; Youdelis et al., 2021). Activities such as establishing national and provincial parks have been used to dispossess Indigenous peoples from their territories and sever long-held relationships to those lands (Marshall et al., 2021). Present-day Canada has made commitments towards reconciliation and upholding Indigenous Rights (i.e., adopting the United Nations Declaration on the Rights of Indigenous People), but still exists within the tension of resource extraction, land dispossession, and unresolved nation-to-nation relationships (Eckert et al., 2020). We invite conservation practitioners to reconsider the assumption of Canadian authority and ownership of land at the expense of Indigenous sovereignty (Eckert et al., 2020; Todd, 2022). In the face of competing conservation crises, settlers may feel justified in the appropriation of Indigenous knowledge or the infringement of Indigenous rights and sovereignty (Goldenberg, 2002; Whyte, 2020). Indigenous knowledge should not be misappropriated to secure settler futures (Martinez et al., 2023), and genuine co-management towards effective stewardship, which benefits all, can only be achieved when Indigenous rights and sovereignty are upheld (Todd, 2022).

5 | CONCLUSION AND FUTURE WORK

In our survey, conservation practitioners in Canada consistently identified elements of uncertainty that exist outside their power to resolve. These included factors like government, funding availability and priorities, organizational support, and law. For example, a conservation practitioner may reduce uncertainty around knowledge by gaining more access to scientific evidence (Walsh et al., 2015), but they typically cannot make a government more amenable to conservation actions. Ostrom (2009) conceptualized these elements as "external variables" in her institutional analysis and design (IAD) framework. The framework posits that social, economic, and political settings may impact action situations being studied. Similarly, the field of economics uses the term "externality" to refer to factors that are outside of a particular economic situation but affect its outcome (Helbling, 2010).

Recent cuts to federal biodiversity conservation funding in the USA are an extreme example of the profound impact of external variables on programs. However, no jurisdiction is immune to changes in funding priorities.

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We suggest that external variables should be more frequently discussed in conservation decision-making regardless of jurisdiction, and that these be explicitly considered alongside other sources of uncertainty in decision-making. Approaches that only consider directly related uncertainty risk irrelevance, since external factors (e.g., suddenly canceled funding) can have catastrophic effects on conservation outcomes. Interdisciplinary work and drawing from the social sciences can provide conceptual and empirical tools to analyze such external variables, including social phenomena, processes, and attributes (Bennett et al., 2017). Adaptive co-management is a tool for managing some of these external uncertainties by providing a pathway to collaboratively addressing them (Welch-Devine, 2012), though it does not remove the possibility of externalities dismantling the endeavor. Science and evidence within and outside the academy also have a role in encouraging public action to change externalities. For example, community/citizen science can provide robust, accessible information for environmental groups to leverage into new conservation tools or advocate for political change. Viewing science as a reciprocal social process allows us to identify the role that evidence and practice can play in relation to these external variables.

It is important to note that practitioners' identities and the marginalization they may face in their field can influence their experience of uncertainty when making conservation decisions. Our study did not collect this demographic data and was not designed to address this aspect of uncertainty in decision making. However, this is an important avenue for future research.

Understanding sources of uncertainty is crucial to effective conservation and requires ensuring external factors are accounted for in ways that incorporate the real experiences of decision-makers. Our results underscore the need to align the realities of conservation decision-making with a broader socio-political context. While much of the uncertainty practitioners shared is outside of their control, many of their proposed solutions highlight actionable areas for both conservation organizations and others to consider.

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CONFLICT OF INTEREST STATEMENT

The author declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are publicly available via this link: https://zenodo.org/doi/10.5281/zenodo.13825928.

ETHICS STATEMENT

Carleton University Research Ethics Board-B (Clearance # 117672).

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