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What is 'good evidence' for environmental decision making? Insights from professionals working at the science-policy interface

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ABSTRACT

Effective protection and management of natural ecosystems demands policies and decisions that are based on the best available evidence. However, it remains unclear how policymakers define evidence and prioritize or neglect different evidence types in environmental decisions. Here we analyze perspectives and experiences of Canadian professionals working at the science-policy interface to develop a definition of "good evidence" for environmental policy, and assess the evidence types (e.g., peer reviewed science, Indigenous knowledge, expert consultation) used most frequently to inform environmental decisions. We derived a new definition of "good evidence" from the participant responses, as follows: *Good evidence for environmental policy is reliable, diverse* ***information*** *collected systematically through* ***established methodologies*** *(including Western social and natural science, Indigenous science, and place-based knowledge accumulated intergenerationally by close and continuous observation) that is* ***credible*** *and* ***yields practical advice*** *or relevant conclusions while being* ***transparent*** *about uncertainties.* We found that a majority of environmental policymakers use peer reviewed literature mostly from the natural sciences to guide policy decisions. Evidence arising from local knowledge, Indigenous knowledge, and the social sciences tends to be neglected. However, there was a sense that perceptions of what constitutes evidence is changing and that implicit biases that prioritize some types of information over others are being questioned. Different conceptions of the salience, credibility and legitimacy of information types fundamentally shape debates around best practices for evidence-informed decision making. We suggest several routes toward a more holistic framing of environmental policy problems.

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1. Introduction

Effective protection and management of natural ecosystems demands decisions that are based on the best available evidence (Sutherland et al., 2004; Dicks et al., 2014; Walsh et al., 2015). However, practitioners and policy makers in environmental fields operate in complex social-ecological contexts and sound decision-making requires consideration of diverse and often competing ecological, economic, social, and institutional factors (Pielke, 2007; Kadykalo et al., 2021). Evaluating and weighing different forms of evidence remains a challenge for decision-makers, especially given variation in the quality and relevance of various evidence types in different socio-cultural contexts (Adams and Sandbrook, 2013; Christie et al., 2023), the relatively short timeframes for policy decisions (Laurance et al., 2012), and the backdrop of ever-changing political priorities (Bowen and Zwi, 2005). Within these complex decision spaces, it is unclear how decision-makers determine which evidence types are prioritized.

Calls for evidence-informed environmental policy stemmed from the efficacy of science-based decision making in medicine (Fazey et al., 2004) and from revelations that environmental policy decisions are frequently based on tacit knowledge, anecdote, and personal experience rather than science (Pullin and Knight, 2001; 2003; Pullin et al., 2004; Sutherland et al., 2004). Useful frameworks have since been developed to guide rigorous uses of scientific evidence in environmental decisions. These frameworks propose hierarchies of evidence quality, prioritizing information emerging from specific approaches (e.g., systematic reviews, evidence syntheses, randomized controlled trials) often favoring Western scientific methodologies (e.g., Dicks et al., 2014; Sutherland and Wordley, 2017; Salafsky et al., 2019; Thomas-Walters et al., 2021; Sutherland, 2022). Critics of this view have suggested that a focus on quantitative methodologies can be restrictive and over-privilege ways of knowing that may not always produce the best evidence for a given policy question (Nutley et al., 2007; Mullen, 2016; Parkhurst, 2017). Calls for consideration of evidence from diverse disciplines, values, interests, and knowledge systems have emerged (Game et al., 2018; Daviter, 2019; Cooke et al., 2020; Kadykalo et al., 2021).

Amidst this complexity, there is a lack of consensus on a definition of "good evidence" for environmental policy (Mayne et al., 2018; Cairney et al., 2016). Defining evidence is challenging because of the diverse issues that environmental policies address, with the specific question at hand determining the types of evidence most needed in each context. Salafsky et al. (2019) broadly define evidence as: "relevant information used to assess one or more hypotheses related to a question of interest" while Mullen (2016) emphasizes effectiveness, context, and outcome as opposed to information source. Parkurst (2017) refers to Cash et al. (2003) suggesting that policy-relevant information must be salient, credible, and legitimate. Several authors have further emphasized legitimacy as being fundamentally important when considering "good evidence" because it highlights diverse social, economic, and environmental values (Cash et al., 2003; Parkhurst, 2017).

Regardless of definition, failure to adequately uphold and account for the knowledge, experience, and perceptions of citizens, rights holders, and stakeholders can undermine the success or acceptance of proposed policies or decisions. The implicit bias toward empirical Western-scientific information and persistent doubts and misunderstandings of other knowledge systems, including their axiological and epistemological underpinnings, hinders policy legitimacy (Lemieux et al., 2018, 2021). Different understandings of evidence and various perspectives on the objectivity vs. subjectivity of information fundamentally shape debates around evidence-informed decision-making (Marston and Watts, 2003; Christie et al., 2023). The definition of what constitutes evidence is thus at an important juncture, as are ideas on how different types of evidence can and should be brought together in decision-making processes.

As social considerations come to the forefront of environmental management conversations, new frameworks are emerging to guide the parallel usage of multiple knowledge or information sources, including (but not limited to) Indigenous knowledge, local knowledge, and qualitative socio-economic data (Bartlett et al., 2012; Tengö et al. 2014; Kealiikanakaoleohaililani and Giardina, 2016; Mantyka-Pringle et al., 2017; Cooke et al., 2020; No'kmaq et al., 2021; Christie et al., 2023). These frameworks have been operationalized by large global conservation initiatives such as the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) whose processes are designed to bridge knowledge systems (Tengö et al., 2017). However, on national or subnational scales, the application of these frameworks is still in its infancy. Ongoing dialogue continues around the equitable treatment of knowledge systems as governments begin to grapple with ideologies outside of Western science approaches (Armitage et al., 2019). Crucially, these knowledge systems go beyond merely being sources of "evidence" or "information", but are rooted in complex worldviews shaped by distinct axiological, ontological, and epistemological foundations that influence not only *how* knowledge is generated, but *which* policy questions are seen as relevant and worth asking (Godfrey-Smith, 2009; Wilson, 2008; Held, 2019). Truly valuing and upholding these knowledge systems requires learning how to best apply the "evidence" or "information" that emerges from them.

Canada provides a globally relevant case from which to explore perspectives on evidence-informed decision-making (EIDM) in environmental spheres (Cooke et al., 2016). Canada has a vast and varied geography, is economically reliant on extraction of natural resources, and has a variety of established and well-funded institutions with advanced scientific capacities (e.g., government bodies, universities, environmental non-governmental organizations (ENGOS)). Governance of Canada's natural resources is shared among federal, Indigenous, and provincial / territorial governments, with additional constitutionally protected rights belonging to Indigenous Peoples (Government of Canada, 2018).

In Canada, awareness of the importance of transparently linking decisions to evidence traces back to the collapse of the Atlantic cod fishery in 1992, leading to the establishment of the Canadian Science Advisory Secretariat (CSAS) within Fisheries and Oceans Canada (Hutchings, 2022). This and other actions taken in response to demands for transparent decision-making represent important progress; however, critical gaps persist in the capacity to engage appropriately with forms of evidence that fall outside of Western science approaches (Stevenson and Webb, 2003; Kadykalo et al., 2021). For example, the Canadian federal government has emphasized the importance of engaging in reparative relationships with Indigenous Peoples both through their calls to action in the Truth and Reconciliation Commission document (TRCC, 2015) and by legislating the implementation of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) (Government of Canada, 2023). However, full recognition of Indigenous Peoples' sovereign rights to lands and waters has not been achieved (McGregor, 2018) and attempts to include Indigenous knowledge in environmental processes are nominal and incomplete (Eckert et al., 2020; Hamelin et al., 2023). Decision makers also struggle to balance other forms of evidence, including social and cultural values, economic interests, citizen perspectives, and local and/or community knowledge. Canada has the potential to serve as a global model for EIDM, but addressing these shortfalls is crucial.

Here, we assess the perceptions and experiences of Canadian professionals working at the science-policy interface in using evidence to inform environmental decisions and/or develop policy recommendations. We look across a broad range of information types that could be considered evidence for environmental policy. We report findings from interview questions on seeking and identifying evidence to inform environmental decisions. We draw on participants' responses to develop a definition of "good evidence" for environmental policy and assess the evidence types used most frequently to inform environmental decisions. We then delve into hierarchies of evidence and assess challenges and barriers to using different forms of evidence in policy and practice.

Positionality statement: *Appropriate engagement with Indigenous knowledge in environmental decision-making forms a central theme in this paper. Although the intent of this work is to discuss a broad array of evidence types, the theme of Indigenous knowledge was emphasized by participants and thus deserves the detailed analysis provided here. However, it is important to note that the interview subjects were not from Indigenous governments, and that members of the research team do not represent Indigenous Peoples. We acknowledge the need to consider the perspectives of other governments and actors to determine wise practices for just and equitable engagement. Where appropriate, we refer to the works of Indigenous scholars (marked with * in the bibliography) and encourage further engagement with these sources.*

2. Methods

2.1. Participant selection and demographics

Participants were recruited via targeted sampling to ensure access to specialized knowledge in policy advising and formulation. We focused on individuals who were either currently employed or recently retired from senior-level positions in environmental departments within three key sectors: the Canadian federal government, territorial or provincial governments, and environmental non-governmental organizations (ENGOs). All participants had experience providing advice for environmental policies, communicating directly with policy makers, or participating in the creation of policy, and we had representation from federal government departments and agencies including Fisheries and Oceans Canada (DFO), Environment and Climate Change Canada (ECCC), Parks Canada, and Natural Resources Canada (NRCan), as well as territorial/provincial governments and ENGOs (Table 1). Participants were identified using a combination of previous relationships and established partnerships (n = 53) and web searches of relevant environmental organizations to recruit individuals in leadership or advisory science-policy roles (i.e., cold calls; n = 23). We also solicited recommendations from individuals included in the initial list (n = 8). Invitations were sent to the potential participants via email. In total, we reached out to 135 individuals and had a 62 % response rate ultimately conducting 84 interviews.

Table 1
Numbers of participants from the Canadian federal government (Parks Canada, Environment and Climate Change Canada, Fisheries and Oceans Canada, and Natural Resources Canada), provincial/territorial governments, and environmental non-governmental organizations (ENGOs) that responded to the interview questions.

Agency, Organization, or Department	N	
Federal Government	49	
Parks Canada		*12*
Environment and Climate Change Canada		*13*
Fisheries and Oceans Canada		*14*
Natural Resources Canada		*10*
Provincial / Territorial Governments	14	
Alberta		*3*
British Columbia		*1*
New Brunswick		*1*
Nova Scotia		*1*
Nunavut		*2*
Northwest Territories		*2*
Ontario		*2*
Saskatchewan		*1*
Yukon		*1*
ENGO	21	
BC Wildlife Federation		*1*
Council of Canadian Academies		*1*
Canadian Parks and Wilderness Society		*2*
Canadian Wildlife Federation		*2*
David Suzuki Foundation		*1*
Evidence for Democracy		*1*
Great Lakes Fisheries Commission		*1*
Island Nature Trust		*1*
Nature United		*1*
Nature Conservancy Canada		*2*
Trout Unlimited		*1*
Waterton Biosphere Reserve		*1*
Wildlife Conservation Society Canada		*2*
World Wildlife Fund Canada		*1*
Yellowstone to Yukon Conservation Initiative		*2*
Yukon Conservation Society		*1*
TOTAL	84	

All participants possessed post-secondary education, with the majority (75 %) holding either a master's or a PhD degree. Their professional backgrounds varied, with some participants primarily focused on policy (n = 8), others primarily engaged in scientific research (n = 9), and a significant number (n = 67) involved in both areas. Notably, the majority (80 %) gained their experience with policy application through on-the-job experience rather than formal training. Among the participants affiliated with departments of the Canadian federal government, 30 were based in Ottawa, Canada's capital city, while 19 were associated with regional offices across different provinces (Table 1). The gender distribution consisted of 36 female and 48 male respondents spanning mid- and late-career stages (from 8 to 30 + years experience).

2.2. Designing and conducting interviews

The interviews followed a semi-structured format, using a scripted set of questions while allowing for flexibility and digressions in conversation. The questions included both closed-ended and open-ended formats, generating both quantitative and qualitative responses. The interview guide was collaboratively written by multiple members of the research team (EAN, JJT, TR, JFL, NY, JB, SJC), and circulated among all 17 co-authors for comment. After 3 months of extensive revisions, the questionnaire was tested with six individuals, including three non-participants and three participants of the study. Based on their feedback, certain questions were either removed or revised. The final questionnaire consisted of 14 questions, covering various aspects such as definitions of evidence, identification of barriers to evidence use, and potential solutions for using evidence in policy and practice (Appendix A). In this article, we report findings from five of these 14 questions that were specifically about approaches to seeking and identifying evidence to inform decision making. The first two questions requested participants to (1) define 'evidence' in their own words and (2) discuss the concept of evidence-informed decision making. Next, we asked participants to (3) outline the primary forms of evidence that they use when developing policy recommendations or decisions, (4) detail their involvement with the research process and (5) describe external sources of evidence that are commonly pursued to inform decisions (Table 2).

Interviews were administered either in person or via telephone by JFL. The interviews were approximately 1 h (average: 1.1 h; range: 0.75 – 1.6 h). All interviews were audio recorded and subsequently transcribed using Trint Automated Transcription software. The transcriptions were carefully reviewed and edited by one of three transcribers to screen for errors. Prior to the interviews, consent to participate in the study was obtained from all interviewees, and strict confidentiality measures were implemented in which participants were given anonymous codes and data was analyzed without personal identifiers in accordance with Carleton University Research Ethics Board file #12486.

2.3. Data analysis

Qualitative analysis was performed using NVivo software (version 12). An initial codebook was developed through a combination of inductive and deductive approaches by EAN and NH, with deductive approaches based on evidence types discussed in several key studies including Pullin et al. (2004), Dicks et al. (2014), Tengö et al. (2014), Salafsky et al. (2019) and Christie et al. (2023). To ensure consistency, two inter-rater reliability tests were conducted on the first round of raw coding. The initial test yielded an average Cohen's K-value of 0.37,

Table 2
Open ended interview questions analyzed in this article.

Interview questions
In your own words, how would you define evidence?
1. What do you think of the idea of "evidence-informed decision-making"?
2. What are the primary forms of evidence used to make policy decisions in your job?
Why are these the main forms of evidence used?
3. Within your role, have you ever conducted original environmental research (i.e., you are directly involved in designing the study, collecting/analyzing/interpreting data, and/or writing the report) mandated by your department/agency/organization?
a) What form does this take? (e.g., short-term studies, long-term monitoring, syntheses)
b) For what purpose? (e.g., in-house use, for other agencies, to inform policy)
c) How often is this done?
4. Within your role, have you ever sought environmental knowledge from outside sources (i.e., external to your organization or government body) to inform decisions?
IF YES:
a) Who do you reach out to?
b) How is this done? (e.g., privately, personally, paid vs unpaid, asking advice, accepting independent reports, etc.)
d) What circumstances prompt you to do so?
e) Has this changed over time?

indicating low agreement. Subsequently, the coders held four meetings over a period of two months to manually compare and discuss their coding choices. Following these meetings, a second inter-rater reliability test resulted in an average K-value of 0.52, indicating fair agreement. Two additional rounds of coding were completed by EAN after the initial coding once the detailed codes were finalized. The final codebook is attached as Appendix B.

Answers to interview Q1 and Q2 were analyzed separately from the rest of the questions. Responses to Q1 were used to formulate a broad definition of evidence. Responses to Q2 were used to evaluate participants' current knowledge and experience with EIDM. Responses to Q3–5 were coded according to several broad themes (Appendix B). In a final round of coding, we qualified whether the respondent indicated that they currently use or do not use the evidence type they were referring to so that we could get a sense of how frequently an evidence type is mentioned vs. how much it is actually used. We created a node titled "Where is evidence sought from for use in environmental policy". We then created sub-codes for common evidence types mentioned in these statements and then classified them according to whether the respondent actively uses the evidence form (i.e., "used") or that the respondent is aware of the evidence form but does not currently use it (i.e., "not used") (Appendix B).

3. Results

3.1. Definitions of "good evidence" for environmental policy

Out of 84 interviewees, 78 offered definitions of evidence. Many mentioned how challenging it is to establish a single definition given how the definition changes with context. Respondents defined evidence based on **inputs** (the information that constitutes evidence), **process** (steps taken to obtain information that can be considered evidence), and **outputs** (the results of using that information as evidence (Table 3). Key elements necessary for information to be considered 'evidence' included measurability, repeatability, systematic collection, verifiability, and linkage to a credible source. For example, one respondent commented: *For me it is data. It's observations either from instruments or by individuals that have a known protocol for acquiring it, and that can be replicated. And that can extend across different cultural approaches. (Interview 015, FED-Parks Canada)*. Another said: *To me it's as inclusive as possible but traceable to a source so that you can identify whether it's independently verifiable scientific data or whether it is expert opinion (Interview 018, FED-Parks Canada)*. Tangible and actionable outcomes were desired. For example: *In general, it is information that, in the mind of a decision maker, changes the probability that a given presumption about the environment is true (Interview 045, FED-Parks Canada)*

Respondents also mentioned considerations such as **quality** and **type** of information, and which **aspect** of the decision the information addresses (Table 3). Examples of information that comprise evidence were discussed with a focus on quantitative (natural) science (n = 62, 79 %) with Western scientific process and peer-reviewed journals seen as the gold standard. Indigenous and/or traditional knowledge (IK or TK)[2] (n = 30, 38 %) and local and/or community knowledge (LCK)[3] (n = 16, 21 %) were also mentioned as sources of evidence. Other elements, such as social and cultural norms (n = 9, 12 %), economic concerns (i.e., economic implications of decisions, n = 7, 9 %), and anecdotal information (n = 7, 9 %) received less attention. Taking these responses into account we arrived at the following working definition of good evidence for environmental policy:

> *Good evidence for environmental policy is reliable, diverse information collected systematically through established methodologies (including*

Table 3
A summary of key elements and considerations that make good evidence for environmental policy. Our analysis revealed that each of the elements below were mentioned by at least 5 respondents (number of respondents indicated in brackets).

Descriptions of evidence	Common themes
Elements of evidence	
Inputs	A set of facts, knowledge, information (n = 13)
Process	gathered systematically, established methods, replicable, traceable to a credible source, assumptions and uncertainties recognized (n = 34)
Outputs	Advice, set of conclusions (n = 5)
Considerations	
Quality	Inclusive, objective, relevant, (credible, salient, legitimate) (n = 9), peer-reviewed (n = 17), synthetic (n = 7)
Type	scientific, Indigenous, local, expert, experiential, practice-based, anecdotal (n = 78)
Aspect	economic, environmental, social, ecological, practice-based (n = 78)

[2] In the context of these interviews, many participants used 'traditional knowledge' (TK) and 'Indigenous knowledge' (IK) synonymously. Although we acknowledge that the term 'traditional' does not encompass all forms of Indigenous knowledge, we combine them in our analyses to be consistent with language used by participants. In many parts of our manuscript, we follow Reid et al. (2022) and use 'Indigenous knowledge' or 'IK' to refer to place-based knowledge created and/or mobilized by Indigenous Peoples that may include traditional knowledge and scientific knowledge.

[3] We use local and/or community knowledge (LCK) to refer to non-Indigenous place-based or community-based knowledge.

Western social and natural science, Indigenous science, and place-based knowledge accumulated intergenerationally by close and continuous observation) that is credible and yields practical advice or relevant conclusions while being transparent about uncertainties.

3.2. Wicked environmental problems prompt shifts in conceptualization of evidence

Respondents emphasized that the "wicked" (*sensu* Rittel andWebber, 1973) nature of environmental problems mean that the evidence required or prioritized for decision making is context specific, complex, and multifaceted. Fifty-four respondents (64 %) spoke about additional considerations that compete with scientific evidence, including economics (n = 23), socio-cultural considerations (n = 21), stakeholder and industry concerns (n = 18), IK or TK (n = 15), political considerations (n = 15), public opinion (n = 13), and LCK (n = 8). There was acknowledgement of the challenges associated with considering, weighing, and comparing multiple knowledge sources, as demonstrated by a participant from DFO:

It's about understanding that there are many different sources of information and that the scientific information sources, which I'm primarily responsible for providing, are not the only sources of information that are used to making decisions. And they shouldn't be the only source of information. The challenge is really how you weigh the various sources of evidence and how to be transparent in how we use the information to make a decision. (Interview 047 – DFO).

These findings point toward the need to dismantle hierarchies among knowledge systems; however, there are still unconscious or implicit biases that uphold some types of evidence as more trustworthy and reliable than others. For example:

Some of the barriers that I've crossed are first the perception that some knowledge is more important or more valid than others. So, people come in with the idea that their knowledge is the one to be considered. And that's a problem. It's a problem within academia who thinks that their knowledge is really the one that should speak for the decision. And that creates an imbalance with different knowledge holders that don't have the same voice or the same power. (Interview 004, ENGO)

There was a tendency among participants to equate 'evidence' with information produced via Western scientific approaches (e.g., *We always try to make decisions that are informed by evidence…which is, you know, science - Interview 028, NRCan*) and, conversely, to equate IK with anecdote, tradition, religion, or personal belief as opposed to systematically collected and dynamic knowledge (e.g., *With traditional or Indigenous knowledge, I feel that it's more difficult to…it's religion to some people. The fact that it's a belief makes me think: should this body of evidence be put forward to the decision maker? - Interview 033; ECCC)*. However, the risks of only considering Western natural science were also articulated. One participant spoke directly about working in silos and overlooking a plurality of knowledge: *I would not advocate that approach in any way shape or form because I don't think it leads to the best decisions. One of the important challenges now is incorporating a real diversity of information and evidence and figuring out how to produce the best decision or policy based on that. (Interview 029, Parks Canada)*. This sentiment indicates that implicit knowledge hierarchies are being questioned and are indeed shifting and evolving with time. For example, one participant stated:

To me the word evidence has kind of evolved through time. I think I used to put more weight on the scientific method and the science evidence, and I think I'm starting to see a lot of other perspectives coming in. And I think maybe just identifying the problem isn't enough - you need to kind of bring people along and bring decision makers along to see that. I don't know. It's about human behavior too and how people respond to things and that is an important part of the equation. (Interview 007, DFO)

Many participants expressed the desire for more holistic consideration of knowledge types. For example, one participant in the ENGO sector stated:

And we've learnt and, I have to say, it's really opening the way. Because I am a scientist and a Western science person by training, it has opened my eyes to really value this non-Western science type of knowledge. It's amazing what is out there. And we are missing it! By not looking at the different forms of knowledge, we are narrowing very much the things we see and the way we can interpret things. But, you know, people still aren't sure how to approach that all the time (Interview 004, ENGO).

An additional layer of complexity arises due to shifting political priorities and the types of evidence that are considered legitimate. Participants noted that some governments simply consider scientific knowledge while others are encouraged or even mandated to employ social science knowledge and human dimensions and/or to "incorporate" IK in decisions. Both sides of this were articulated by the same participant from the ENGO sector:

Another interesting thing is the political climate in which environmental groups have been operating. In the Harper[4] years scientists were forbidden to talk to environmental groups and government…that changed quite dramatically when the Liberals[5] were elected. And another thing that has changed is the engagement with Indigenous Peoples under the reconciliation agenda, especially in the north when the land claim agreements are being settled. Those decisions have to be based on science and traditional knowledge - it is not an option to just use science. So, I think that has changed us a bit in that we need to figure out how to deal with traditional knowledge better than we have in the past. (Interview 078, ENGO).

This remark illustrates that definitions of evidence can evolve and that definitions of "good evidence" are likely to shift and change along with societal values and political priorities.

3.3. Forms of evidence are currently used or not used

Outcomes of the exploration of the types of evidence currently used and those not currently used are presented in Fig. 1 in order of most to least mentioned. The top five evidence types mentioned (whether used or not used) included IK or TK, academic peer-reviewed research, government reports, research conducted internally, and expert network consultation (Fig. 1). The top forms of evidence that are currently used related to Western science and referenced quantitative or empirical research whereas the forms of evidence that were most mentioned as not being used were those relating to forms of knowledge that had social or cultural elements such as IK/TK, LCK, and information emerging from social science research (Fig. 1). Although IK/TK was mentioned often, it is mostly mentioned as not being used. We analyzed the top five answers by sector to identify potential sectoral differences in the evidence types used or not used. This analysis revealed little variation in the forms of evidence in use (Fig. 2A), but more variation in the forms of evidence not currently in use (Fig. 2B).

Reasons why certain forms of evidence were or were not actively being used were grouped into two categories: individual and institutional (Table 4). Individual reasons relate to participants' personal worldview, axiology and epistemology, and their familiarity and comfort with the underlying processes and assumptions inherent to a given form of evidence (e.g., the methodology used to create the evidence is well understood). Institutional reasons relate to practical, technical, and

[4] Stephen Harper served as the Prime Minister of Canada from 2006 – 2015 as leader of the Conservative Party of Canada

[5] Justin Trudeau was elected Prime Minister of Canada in 2015 as leader of the Liberal Party of Canada

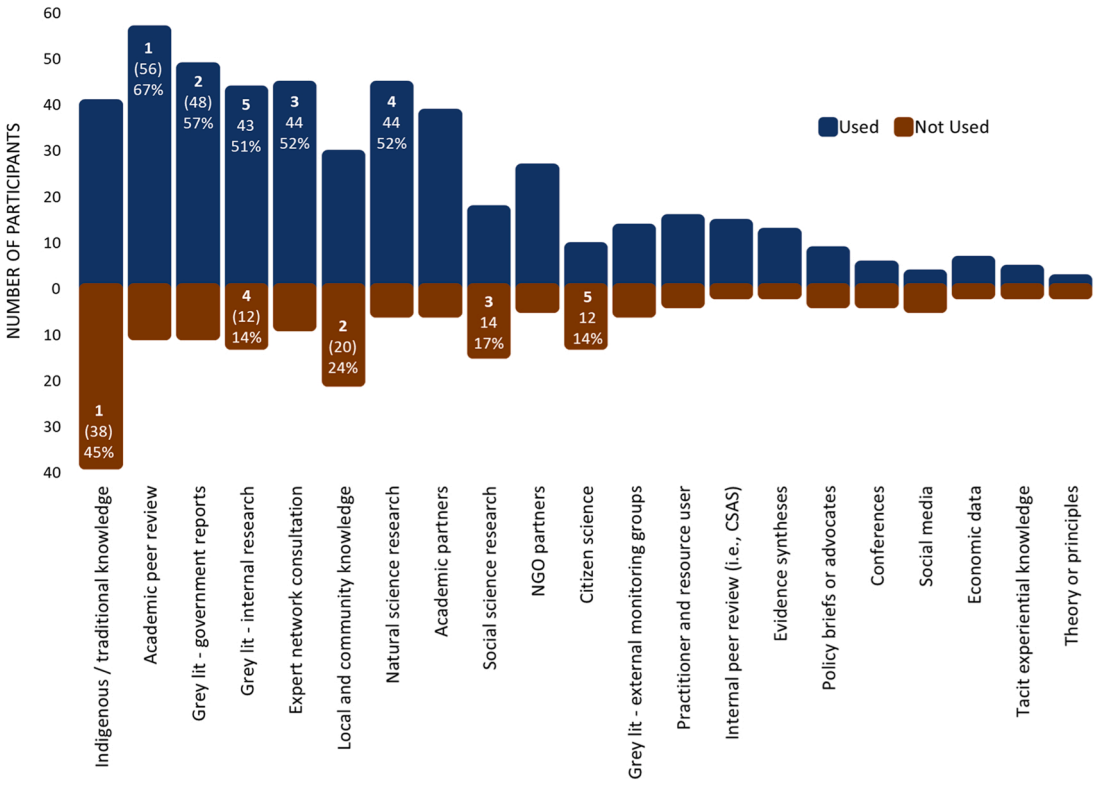

Fig. 1. Sources of evidence mentioned by participants in relation to their use in informing environmental policy presented in order from most to least often mentioned, overall. Orange indicates the number of participants who mentioned that the evidence type **is not** currently used, and the blue indicates the number who mentioned the evidence type **is** currently used. Number and proportion of all respondents for the top 5 used and not used forms of evidence are indicated within the bars.

Fig. 2. The top 5 evidence types that were (A) mentioned as currently being used to inform policy and (B) mentioned as NOT currently being used to inform policy. Bar colours indicate proportions of individuals from each sector (e.g., Federal agency, ENGO, Provincial government) that mentioned each form of evidence. Categories that could have overlap (e.g., natural science research and peer review) were coded separately when participants mentioned one without mentioning the other. If a participant mentioned both in one statement (e.g., "peer reviewed natural science research") this statement was coded to both categories. Detailed descriptions are presented in Appendix B.

bureaucratic factors that facilitate or restrict the use of different evidence forms (e.g., the evidence is difficult to access).

3.3.1. *Used: academic peer review*

According to many participants, the top form of evidence currently used to inform policy is scientific research that has undergone academic peer review. Responses included both social and natural sciences; however, most referred to natural science. Respondents value peer review above other forms of evidence for both individual and institutional reasons (as defined in Table 4). Individual decision makers trust the knowledge system that produced the information (i.e., it has been vetted by a community of experts and can be traced back to the source. For example:

> *It must be peer reviewed. And when you get something that is peer reviewed it's like a light switch goes from non-evidence to evidence. And that is a huge deal when we go to our decision makers and stakeholders because then those decision makers feel confident and the stakeholders*

Table 4
Summary of themes for why certain forms of evidence are or are not used.

	INDIVIDUAL (reasons relating to personal worldview, axiology, and epistemology)	INSTITUTIONAL (reasons relating to practical, technical, and bureaucratic structures)
WHY IS EVIDENCE USED	· Fits what is accepted/expected (status *quo*)	· Trained how to collect, understand, and interpret the knowledge
	· Understand and trust the knowledge system and associated methodologies that produced it	· The knowledge is easy to access
		· The evidence provides rapid answers
	· Provides insight on the most important consideration in the decision-making process (e.g., economic gain, resource sustainability, social equity)	· Implementation of the ensuing policy is feasible with current personnel expertise and financial capacity
WHY IS EVIDENCE NOT USED	· Does not fit into what is currently accepted/expected (outside the status quo)	· Not trained how to collect, understand, and interpret the knowledge
	· Weak literacy in the types of evidence	· The knowledge is difficult to access
	· Do not understand or trust the knowledge system and associated methodologies that produced it	· Time structures do not permit consideration of challenging forms of evidence
	· Competing values and considerations	· Implementation of the ensuing policy is not feasible

feel a pressure that this is really something, not just some one-off. People can find it, people can cite it, and they feel more confident in those decisions. (Interview 010, ECCC).

On the other hand, some respondents indicate that peer-reviewed information is not always policy-relevant, and that they do not have time or are unable to access published literature.

3.3.2. Used: grey literature

Grey literature (e.g., reports or syntheses produced by government agencies) is used at nearly the same frequency as academic peer-reviewed literature. Key reasons for use relate to institutional considerations of practicality (i.e., the knowledge is easy to access) and applicability (i.e., the evidence highly relevant) (Table 4). Some individuals who do not work within government indicated that government reports can be difficult to access; however, many indicated that the public availability of these reports made them more accessible than some paywalled academic literature.

3.3.3. Used: expert network consulting

Expert network consulting was another important route to obtain relevant knowledge for decision making. Many respondents noted that consulting with experts was an efficient, effective, and trustworthy way to find answers to problems rapidly. For example, one participant from Parks Canada mentioned: *"We are not always best equipped to do a systematic, rigorous, complete…analysis. The question needs to be answered more quickly. You just grab the phone, and you call who you know right away." Interview 019*. And another mentioned: *If we're looking for more information to try and fill in some gaps or uncertainties and … we know that a decision is likely to be contentious, we want to get the opinions of experts in the field before making the decision to ensure the decision is robust and to try and get more buy-in (Interview 017, ECCC)*. Participants indicated that the experts who are typically consulted tend to be individuals who are already connected with a network of decision makers and are thus trusted. Importantly, with many expert networks there are histories of partnership and mechanisms for financial compensation already in place. While efficient, this approach can perpetuate systematically held, false, or unsubstantiated beliefs as we discuss below.

3.3.4. Not used: Indigenous and/or traditional knowledge

Indigenous and/or traditional knowledge was the most frequently discussed form of evidence that is *not* currently used in practice for both individual and institutional reasons (as defined in Table 4). On an individual level, many indicated that IK is "*not considered evidence per se*" (*Interview 007, DFO*) due to (mis)understandings that IK is synonymous with 'anecdote' or 'religion' or that IK falls outside of knowledge types typically accepted in policy spheres. Indigenous knowledge can also contradict scientific findings or economic arguments (i.e., competing values and considerations), which can further perpetuate biases against it and make implementation of decisions difficult. Other challenges to engaging respectfully with IK at the science-policy interface emerged. For example:

We've got a wealth of folks who are interested in Indigenous perspectives and traditional knowledge…but many of the communities are being swamped with researchers probing them for information and advice. And one of the things that an elder was telling me - he said: 'You know, they come in, they do this, they run this research, and that's the last we hear of them…they never ever connect back'. And so, they said what they do now is to stop doing the research. (Interview 014, NRCan)

Many wish to engage with IK, but encounter barriers. For example, one participant stated: *I have to say that we talk a lot about Indigenous knowledge, but we don't use it very much. We'd like to, but we don't have the know-how, the capacity, or the time. (Interview 015, Parks Canada)*. Others discussed the difficulty of being mandated to "use" Indigenous knowledge without training. For example: *Sometimes we're mandated that we have to consult with First Nations, so we do. And that might include asking them for their knowledge or their data, right, which comes with other [considerations]. And sometimes we know it's the right thing to do. So, we do it, but it's not…done well." (Interview 021, ECCC)*. Those that do engage with IK are those that have developed relationships with First Nations, Métis, and Inuit communities over longer time scales. These individuals point out that IK can provide highly relevant information for policy.

3.3.5. Not used: local and community knowledge (LCK)

Local and community knowledge (LCK) was similarly valued but not well understood. Some participants mentioned that they only turn to LCK when the necessary data is lacking from the scientific literature. Some noted that while they did not necessarily have the skills or capacity to engage in LCK they recognize that there is impetus for it and a movement to include LCK more.

I think that we're moving along the path to recognize and accept knowledge within individuals. Working with other people through their daily life experience that have bodies of knowledge…if you were a rancher who for 30 years sees your landscape and has accumulated knowledge in a way

parallel to the traditional knowledge and might be as acceptable as scientific knowledge (Interview 075, NWT Government).

Many indicate that, although the use of evidence from social science research is starting to be valued, there is a lack of capacity within departments to conduct or understand social science research. Most organizations have weak or non-existent social science programs.

4. Discussion

4.1. Definition of "good evidence" for environmental policy

The definition of what constitutes "good evidence" for environmental policy is at an important juncture, as are ideas on how different types of evidence can and should be included in decision-making processes. Respondents' awareness of the complexity and context-specificity of most environmental decisions aligns with arguments from the science-policy literature that perceptions of the salience, credibility, and trustworthiness of knowledge will vastly differ depending on a given socio-political setting (Mullen, 2016; Christie et al., 2023). The definition of evidence provided in this paper is thus descriptive and broad with themes covering information type, process, and efficacy, and can be seen as a guide to determine whether information meets qualifications of "good evidence" in each context.

4.2. Evolution of evidence-informed decision making: reformulating dialogue

In the science-policy literature, discussions about evidence are often reduced to the question of whether policymakers use scientific evidence in their decisions. But policy decisions almost always rely on multiple evidence types, and there are no standards outlining when and how to use them. There tends to be a bias toward the use of empirical, natural science approaches to informing environmental policy decisions. However, public policy scholars have long argued that in democratic political systems, policy decisions are influenced by a diversity of competing arguments, conflicts, trade-offs, and compromises (Adams and Sandbrook, 2013; Head, Alford, 2015). Relying solely on Western scientific evidence for confronting policy problems that have ingrained social elements (i.e., most environmental decisions) is likely to fail (Parkhurst, 2017).

Participants in this study observed advancements in evidence-informed decision-making (EIDM), both in terms of consistency and diversity of evidence type. Many noted that institutional constraints tie them to certain evidence types but recognized that exclusively relying on Western science may not lead to equitable or effective policy decisions. This aligns with sociological perspectives that have highlighted how social norms, ideologies, and power relations shape knowledge creation and conceptions of what qualifies as evidence (Turner, 2001), and that what is considered evidence can depend greatly on the dominant ideologies of political systems and change with new governments (Mayne et al., 2018). This study suggests a growing recognition of the need for diverse information sources, potentially challenging hierarchical knowledge structures that may hinder the use of non-Western scientific evidence. Enhancing evidence use that includes a plurality of knowledge sources involves addressing normative and epistemological differences among different knowledge types to reduce bias in decision making for environmental policy (Hoelting et al., 2024). Instead of simplistic calls for more evidence-based policy, a deeper exploration of the origins of policy biases may be needed (Parkhurst, 2017; Mayne et al., 2018). This ongoing evolution and redefinition of "evidence" and "evidence use" requires further attention and guidance.

4.3. Exploration of use or non-use of different evidence types

4.3.1. Peer-reviewed science

Respondents demonstrated a high reliance on peer-reviewed science to inform decisions, whether from academia or internal research bodies. This may indicate a movement away from the problem of "evidence complacency" (Pullin et al., 2004; Sutherland and Wordley, 2017), and can provide impetus for researchers and funders to pursue applied research. Guidance for both researchers and funders on best practices to produce actionable science encourages transdisciplinary approaches, promotes better knowledge exchange among sectors, and advocates for inclusive training programs (Cooke et al., 2020; Nyboer et al., 2021). There is still room for improvement (Piczak et al., 2022). There is a bias toward the natural versus social sciences despite increasing calls from diverse sectors to integrate qualitative data. Staffing trained social scientists in government departments and at science-policy interfaces is a relatively straightforward solution that has been suggested (Bennett et al., 2017) to lower existing institutional and ideological barriers for integrating qualitative evidence.

Our study also revealed a high reliance on science produced in-house. While this approach offers advantages such as relevance and rapidity of production compared to external sources, it carries the risk of political bias, especially if mandated by a specific policy entity (Parkhurst, 2017; Daviter, 2019). Previous work has shown that high reliance on information produced in-house can lower innovation because of the repetitive nature of routine studies and that bringing in external work can lead to novel ideas (Head, 2013). To mitigate this, organizations relying heavily on internal reports should ensure diverse expertise within their research teams to provide comprehensive policy recommendations. Structural and transformative changes are necessary to help support systematic inclusion of diverse types of evidence.

4.3.2. Networks of experts

Consultations with networks of experts can efficiently deliver relevant information for environmental decision-making facilitating rapid outputs, akin to in-house research. However, an excessive reliance on expert knowledge risks undermining policy legitimacy by favoring those already entrenched in policy circles, further marginalizing underrepresented knowledge types and exacerbating inequities in knowledge valuation (Parkhurst, 2017). Turner (2001) argues that notions of what comprises 'expertise' and definitions of who are considered 'experts' are mutable and subject to reconstruction throughout the policy process. Accepting their contestability and allowing for flexibility is a key part of re-imagining what an expert network can look like. We do not discount the potential value of expert consultation in policy creation, but rather argue that systems of consultation and investments in expertise must be re-thought. This involves substantial efforts to broaden expert networks, establish engagement protocols that respect diverse knowledge types, and ensure fair and equitable compensation for all experts on their terms.

4.3.3. Indigenous knowledge

Interviews highlighted a strong willingness to draw upon Indigenous knowledge in environmental policy spaces, yet significant confusion remains on how to engage appropriately. The Canadian government's commitment to Indigenous reconciliation is evident through initiatives like the Truth and Reconciliation Commission (TRCC, 2015), the UN Declaration Act (UNDA) enacted in 2021, and its subsequent Action Plan (Government of Canada, 2023). In response, various environmental acts have made space for, or even mandated, that policy decisions should account for diverse considerations, including IK and LCK (Crawford et al., 2018; Eckert et al., 2020; Hamelin et al., 2023). Despite these efforts, critics argue that current approaches inadequately address the historical and ongoing impacts of colonization (Usher, 2000; Paci et al., 2002; Ellis, 2005; Ballard, 2017; Craft, 2019; Ignace et al., 2023) and may even be unconstitutional (Metallic, MacIntosh, 2020). Indigenous

Peoples in Canada still face limited control over their lands and resources, with Indigenous knowledge often marginalized and viewed as supplementary to Western science (McGregor, 2021).

Despite growing acceptance of IK and LCK in environmental management (Turner et al., 2000; Houde, 2007; Berkes, 2012; Housty et al., 2014) and increased scrutiny of Western scientific dominance (Menzies and Butler, 2007; Leonard et al., 2020), a perceived hierarchy of knowledge continues to hamper the application of Indigenous knowledge in environmental policy processes. There remains much resistance in environmental spheres (especially at the federal level) to share real decision-making power to members of Indigenous communities whose sovereign territories are affected by environmental decisions (Black and McBean, 2016; Crawford, 2018; Eckert et al., 2020; Metallic and MacIntosh, 2020; Todd, 2018). Public servants often view mandates to consult or "incorporate" IK as obligations without clear understanding or guidance on how to proceed (Kadykalo et al., 2021; Reid et al., 2024). Mandates to consult Indigenous communities are relatively new, and there are few examples of successful engagement to serve as models. Establishing a repository of case studies with defined procedures and successful outcomes could prove beneficial.

Challenges in defining IK are common at the intersection of IK, environmental policy, and ecological research (Nadasdy, 1999; Agrawal, 2002; Berkes, 2012). These failures stem from the colonial nature of Canadian legislation and are perpetuated by assumptions of the superiority of Western scientific knowledge (Paci et al., 2002; Ellis, 2005; Butler and Menzies, 2007; Berkes, 2012). In an examination of DFO policy documents, Hamelin et al. (2023) found that “Aboriginal Traditional Knowledge” or ATK was rarely mentioned, and then its “incorporation” into decisions problematically framed as an aspiration rather than a concrete action, with consultations frequently lacking meaningful impact. In addition, Indigenous communities have expressed legitimate concerns over knowledge exploitation and appropriation. Problems arise as the integration or incorporation of IK is seen by some as a form of neo-colonization, where IK is detached from its cultural context and forced to conform to Western science norms (Butler and Menzies, 2007; Denny and Fanning, 2016; Chiblow, 2023; Mussett et al., 2023). The outcomes lead to Indigenous resistance, strained intergovernmental relationships, and further exclusion of Indigenous viewpoints in decision making.

4.4. Thinking forward

4.4.1. Co-frame the policy problem to decide on evidence priorities

This investigation highlights that enhancing evidence-informed decision making (EIDM) entails more than bridging the gap between evidence and policy; it involves understanding how policymakers prioritize evidence types and elucidating factors that influence the use or neglect of a given evidence type in environmental decisions. Knowledge hierarchies suggested in early EIDM studies can be useful but tend to fall short given their prioritization of empirical knowledge and their reductive tendencies (Daviter, 2019). Environmental policy encompasses a wide array of questions and issues, and the nature of the specific policy at hand often dictates the type of evidence required. For instance, social science evidence is typically essential when addressing issues involving human communities, while natural science evidence tends to be more applicable to fundamental ecological or biological concerns. Much progress is still required to achieve the knowledge plurality and participatory approaches espoused as routes to creating good environmental policy (Parkhurst, 2017; Hoelting et al., 2024). Next steps require moving beyond definitions of evidence and aiming to understand the procedures underlying the framing of the policy problem more deeply. The issue is not always a lack of high-quality evidence; too much evidence can be detrimental when overshadowed by incompatible perceptions and interpretations. Deliberative modes of policy inquiry emphasize participatory policy creation amid uncertainty (Daviter, 2019). Tailoring each problem’s approach and collectively framing policy questions, priorities, and outcomes can guide evidence selection, timelines, and flexibility in framing processes (Cooke et al., 2023; Christie et al., 2023).

4.4.2. Re-structure the policy-making process

Much of the evidentiary heavy lifting for many policy decisions is done by scientists who are either internal researchers or external consultants (academics, consulting firms) who have been mandated by a governing body to produce information (Eckert et al., 2020; Hamelin et al., 2023). There is evidence that individuals who collaborate regularly and have frequent interactions are more open to the perspectives of colleagues within that group (Head, 2013). In contrast, they may exhibit a reluctance to embrace change or new knowledge from those outside the group (Lemieux et al., 2018). It is important to think beyond simply “consultation” or providing “a seat at the table” in policy making processes, and go a step further giving true, equal, and independent authority to voices that represent other paradigms, epistemologies, and ontologies. Working regularly alongside diverse individuals on co-defined problems and outcomes will help to understand forms of evidence (e.g., community-based knowledge) that may otherwise be perceived as being difficult or time consuming. This co-development approach will also dismantle both structural and institutional barriers to knowledge exchange (Cooke et al., 2020).

4.4.3. Elevate the place of Indigenous knowledge in environmental decision-making

There is a deficiency in Canadian public policy when it comes to meaningful engagement with Indigenous communities. This has led to a dependence on the "duty to consult" without clear and specific guidance (Crawford, 2018), resulting in a one-way flow of information and knowledge (Black and McBean, 2016). We recommend shifting towards community-based participatory approaches with Indigenous involvement at all decision-making stages. Indigenous scholars offer frameworks, guidance and theory that can guide good partnerships and enhance Indigenous leadership in environmental decision-making spaces (Lickers, Story, 1997; TallBear, 2014; Ballard, 2017; McGregor et al., 2018; Liboiron, 2021; Ignace et al., 2023; Stirling et al., 2023; Reid et al., 2021; 2024). Including IK in environmental decisions is crucial for recognizing inherent rights, facilitating meaningful Indigenous participation, and promoting self-determination (Ellis, 2005; McGregor, 2004; Mussett et al., 2023; Ignace et al., 2023). Government departments desiring to partner with Indigenous Peoples must restructure their efforts to mold to Indigenous protocols, including co-designing questions and approaches, developing agreements on engagement, knowledge sharing, and data sovereignty, and fairly compensating Indigenous knowledge keepers for their time and expertise.

5. Conclusion

Understanding how policymakers define evidence and prioritize or neglect different evidence types in environmental decisions is critical for ensuring that environmental policies and decisions are salient, credible, and legitimate. Our analysis of the perspectives and experiences of Canadian professionals working at the science-policy interface led to a new definition of “good evidence” for environmental policy as reliable, diverse information collected systematically through established methodologies that is credible and yields practical advice or relevant conclusions while being transparent about uncertainties. While most environmental decision makers adhere to evidence types emerging from Western science approaches, there is an evolution in mind set and evidence Indigenous knowledge systems, local and/or community knowledge and social science gaining prominence. Nurturing these conversations and putting emerging guidance frameworks into practice are critical tasks for academics, decision makers, and governments at all levels.

CRediT authorship contribution statement

Aitken Susan M: Writing – original draft, Investigation, Writing – review & editing, Methodology, Conceptualization. **Bennett Joseph R:** Writing – review & editing, Methodology, Formal analysis, Conceptualization, Writing – original draft, Investigation, Data curation. **Nathan Harron:** Writing – review & editing, Formal analysis, Writing – original draft, Data curation. **Trina Rytwinski:** Writing – original draft, Methodology, Formal analysis, Writing – review & editing, Project administration, Investigation, Conceptualization. **Steven Alexander:** Writing – original draft, Investigation, Writing – review & editing, Methodology, Conceptualization. **Cooke Steven J:** Writing – review & editing, Supervision, Project administration, Investigation, Formal analysis, Conceptualization, Writing – original draft, Resources, Methodology, Funding acquisition, Data curation. **Lane John Francis:** Writing – original draft, Methodology, Formal analysis, Conceptualization, Writing – review & editing, Project administration, Investigation, Data curation. **Nathan Young:** Writing – original draft, Formal analysis, Conceptualization, Writing – review & editing, Methodology, Data curation. **Paul Allen Smith:** Writing – original draft, Investigation, Writing – review & editing, Methodology, Conceptualization. **Smokorowski Karen E:** Writing – review & editing, Methodology, Conceptualization, Writing – original draft, Investigation. **Nguyen Vivian M:** Writing – review & editing, Methodology, Conceptualization, Writing – original draft, Data curation. **Nyboer Elizabeth A:** Writing – review & editing, Visualization, Project administration, Investigation, Data curation, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Jacob Aerin L:** Writing – original draft, Investigation, Writing – review & editing, Methodology, Conceptualization. **Kent Prior:** Writing – review & editing, Methodology, Conceptualization, Writing – original draft, Investigation. **Kadykalo Andrew N:** Writing – original draft, Writing – review & editing, Formal analysis. **Graeme Auld:** Writing – review & editing, Methodology, Conceptualization, Writing – original draft, Investigation. **Brown David:** Writing – review & editing, Writing – original draft, Investigation, Methodology, Conceptualization.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2025.104176.

Data availability

The data that has been used is confidential.

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