*Environmental Conservation*

cambridge.org/enc

## Perspectives

**Cite this article:** Michaels S et al. (2023) Conservation, uncertainty and intellectual humility. *Environmental Conservation* **50**: 196–201. doi: 10.1017/S0376892923000176

Received: 9 September 2022
Revised: 13 July 2023
Accepted: 13 July 2023

**Keywords:**
Conservation; humility; uncertainty

**Corresponding author:**
Sarah Michaels; Email: michaels2@unl.edu

© The Author(s), 2023. Published by Cambridge University Press on behalf of Foundation for Environmental Conservation. This is an Open Access article, distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives licence (http://creativecommons.org/licenses/by-nc-nd/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided that no alterations are made and the original article is properly cited. The written permission of Cambridge University Press must be obtained prior to any commercial use and/or adaptation of the article.

# Conservation, uncertainty and intellectual humility

Sarah Michaels[1,2], Graeme Auld[3], Steven J Cooke[2,4,5], Nathan Young[6], Joseph R Bennett[2,4] and Jesse C Vermaire[2,4]

[1]Department of Political Science and the University of Nebraska Public Policy Center, University of Nebraska, NE, USA; [2]Institute of Environmental and Interdisciplinary Science, Carleton University, Ottawa, ON, Canada; [3]School of Public Policy and Administration, Carleton University, Ottawa, ON, Canada; [4]Department of Biology and Canadian Centre for Evidence-Based Conservation, Carleton University, Ottawa, ON, Canada; [5]Department of Geography and Environmental Studies, Carleton University, Ottawa, ON, Canada and [6]School of Sociological and Anthropological Studies, University of Ottawa, Ottawa, ON, Canada

**Summary**

Interventions in environmental conservation are intended to make things better, not worse. Yet unintended and unanticipated consequences plague environmental conservation; key is how uncertainty plays out. Insights from the intellectual humility literature offer constructive strategies for coming to terms with uncertainty. Strategies such as self-distancing and self-assessment of causal complexity can be incorporated into conservation decision-making processes. Including reflection on what we know and do not know in the decision-making process potentially reduces unintended and unanticipated consequences of environmental conservation and management decisions. An important caution is not to have intellectual humility legitimate failing to act in the face of uncertainty.

## Introduction

A key challenge in environmental conservation is devising interventions that make things better, not worse, yet unintended consequences are pervasive in conservation decision-making (Pearson et al. 2022). One source of unintended consequences is the treatment of uncertainty, which can be broadly defined as 'any departure from the unachievable ideal of complete determinism' (Walker et al. 2003, p. 8). Conservation decisions involve finding ways to resolve the tensions between wide-ranging and tightly intertwined uncertainties in social, economic and ecological systems (Campbell et al. 2010, Hirsch et al. 2011, Schultz 2011). Human–ecosystem interactions can be unpredictable given the potential for complex feedbacks (Low et al. 1999). Uncertainty is further elevated by emerging threats and stressors with unknown or interacting effects (Folt et al. 1999). Conservation science and practice have thus rightly placed considerable attention on uncertainty in efforts to improve the ability to guide policy decisions and management practices in order to achieve positive conservation outcomes.

Given that conservation uncertainties are diverse and multi-levelled, efforts to seek out new knowledge and question existing knowledge are useful for mitigating against unanticipated and unintended consequences in conservation interventions. While studies of intellectual humility continue to develop, existing evidence suggests that intellectual humility is correlated with capacities to acquire new knowledge and assess the strength of evidence for arguments, even when these arguments contradict one's own prior positions (Porter et al. 2022b, Leman et al. 2023). Porter et al. (2022a, p. 573) describe intellectual (or epistemic) humility as 'a constellation of thoughts and behaviors related to productively handling one's intellectual fallibility and ignorance'. Thinking about intellectual humility as a state of mind in a specific situation rather than an inherent personality trait (Porter et al. 2022a) means that it can possibly be fostered in specific decision-making processes.

While strategies to incorporate uncertainty in conservation are well developed and continue to evolve (Walker et al. 2003, Milner-Gulland & Shea 2017, Henderson 2018) and the need for humility in conservation has been acknowledged (Knight et al. 2019, Rice 2022), scant attention has been paid to bundling conservation, uncertainty and intellectual humility. A search in early 2023 for peer-reviewed papers combining all three of the terms 'conservation', 'uncertainty' and 'humility' on the Web of Science, which provides access to multiple databases of academic references, yielded no results. It is in this context that we make a modest, timely proposal: to approach uncertainties in conservation decision-making through the lens of intellectual humility. We propose that burgeoning research and thinking on intellectual humility can offer conservation science a means by which to underpin fruitful decision-making strategies for recognizing uncertainty and acting in the face of it.

A focus on intellectual humility, we suggest, can highlight the importance of recognizing the uncertainty of one's understanding and emphasize the act of searching for and appreciating alternative views that may recalibrate societal understanding of a given subject, issue or conservation problem and management approach. A focus on intellectual humility – and behaviours by conservation professionals (including researchers and practitioners) that are consistent with this form of humility – can offer a way to approach uncertainty that is aligned with conservation goals.

Intellectual humility enables coming to terms with the inherent uncertainty of living systems and the inability to fully comprehend and investigate all aspects of constantly evolving systems (Knight et al. 2019). Being humble involves: astutely assessing what one can do and has done; one's errors, shortfalls, limitations and what one does not know; being amenable to considering novel conceptualizations and content that conflict with one's own position; appreciating one's place in wider systems; limiting tendencies to self-focus; and a respect for the value of all that makes up the biosphere and the different ways in which value is added to the world by others, humans and non-humans alike (Tangney 2000, 2009). Knight et al. (2019) see humility as a tenet in purposively achieving holistic conservation, attending to the interconnectedness between people and the world in which they live. It can be the basis of trust and foundational in collaborating with others (Knight et al. 2019). Consequently, Rice (2022) views humility as an important leadership characteristic in collaborative, community-based conservation, and the concept of humility was identified by early-career trainees as an essential aspect of becoming an effective environmental problem-solver (Gale et al. 2022). Integral to intellectual humility is owning human limitations by examining them thoughtfully and confronting their implications (Whitcomb et al. 2017, Hoekstra & Vazire 2021).

We propose that viewing uncertainty in environmental conservation decision-making through a lens of intellectual humility may offer a form of conceptual anchoring for a range of emerging and productive approaches in conservation science and practice. Calls for intellectual humility should not be seen as inevitably beneficial, particularly when they are strategically deployed to bolster cases for delay and inaction on pressing conservation issues (see Ballantyne 2023). But there appear to be fruitful opportunities to use the growing work on intellectual humility (for recent reviews, see Light & Fernbach 2020, Porter et al. 2022b) to inform efforts to increase the effectiveness and avoid at least some of the unintended and unanticipated harms of conservation interventions.

The format of this paper is as follows. We first highlight two well-accepted features of uncertainty in environmental conservation decision-making that are ripe for constructive reconsideration though the lens of intellectual humility. Two specific strategies for fostering intellectual humility are then discussed. The application of intellectual humility to environmental conservation decision-making is then considered by building on emerging best practices in environmental conservation decision-making. We conclude by providing an invitation to researchers and practitioners to consider employing intellectual humility in a non-naïve manner.

## Features of uncertainty in environmental conservation decision-making

Two features of uncertainty stand out as potentially consequential in contributing to unintended and unanticipated conservation decision-making outcomes. They are the lack of a common understanding of what uncertainties exist and that research does not always resolve uncertainties.

First, conservation decision-making rarely involves settings where a common understanding of what uncertainties exist can be assumed. It is not surprising, given the myriad ways uncertainty can be understood, that uncertainty lacks a universally accepted, exact definition and a precise solution (Regan et al. 2002, Syrett & Devine 2012, Milner-Gulland & Shea 2017). Linguistic uncertainty refers to the absence of consensus about how uncertainty is conceptualized and expressed (Milner-Gulland & Shea 2017). Regan et al. (2002) distinguish between uncertainty in language and in facts, and Milner-Gulland and Shea (2017) differentiate between sources of uncertainty depending on their importance to management outcomes and controllability. The roles that individuals play in policymaking can also affect what uncertainty they focus on. For example, policymakers and stakeholders are often more preoccupied with political or policy uncertainty than scientific uncertainty (Young et al. 2016). At the broadest level, perceptions of uncertainty may reflect cultural norms that vary both through time and among different communities of people (Scoones 2019). How uncertainty is considered is a function of how people view the world (Douglas & Wildavsky 1982). Intrinsic and external factors can shape individuals' tolerance for uncertainty (Slovic 1987).

Second, as much as researchers might wish that they could help resolve uncertainties, this often is not the case. Not all types of uncertainty, including those related to stochastic events and environmental and climate variability (Kremer 1983, Fatichi et al. 2009), can be 'overcome' by research. Those working within the framework of adaptive management have demonstrated that there are many types of uncertainty, and they distinguish between epistemological uncertainty, which can be reduced through studying the phenomenon of interest, and aleatory uncertainty, which cannot (Regan et al. 2002, Keith et al. 2011, Runge et al. 2011).

Conservation decisions are rarely made exclusively based on conservation science. In such settings, generating more conservation science will often not address what is most impeding achieving desirable conservation outcomes. Problems that are not specific to ecology, such as economic conditions, and associated priorities, such as reducing government expenditures, feature significantly in conservation decision-making. For example, the Canadian Species at Risk Act gives the responsible minister discretion in accepting scientific advice on species listings. Recovery implementation plans and timelines are often delayed and ineffective (Bird & Hodges 2017). Implementation of the European Union's Birds and Habitats Directives through Member States introduces uncertainties in how policy design is translated into action on the ground for species and habitat protection (Alblas & van Zeben 2023). In these cases, the political and policy processes represent the locus of uncertainty, more so than the ecological system under threat.

Intellectual humility, as we discuss in the next section, may help us to navigate these features of uncertainty. It may be valuable in helping researchers and decision-makers to be self-aware of their intellectual limits and to seek out enriching their understanding of a situation. Doing so may lessen the possibility of bringing about unintended and unanticipated effects of conservation decision-making.

## Fostering intellectual humility in decision-making processes

A growing body of work in philosophy and psychology offers promising insights into the ways in which individuals are and

https://doi.org/10.1017/S0376892923000176 Published online by Cambridge University Press

can become more intellectually humble (Light & Fernbach 2020, Porter et al. 2022b). The value of these insights, we suggest, is specific to how they may inform conservation decision-making to better navigate uncertainties. This can be accomplished by building procedures into evidence-based decision-making processes that promote recognizing the views of others, self-awareness of intellectual limitations and assessing one's own knowledge. Two specific strategies offer potential in this regard.

First, what is termed 'self-distancing' serves as a means by which individuals can become more reflective and aware of their intellectual limits. Self-distancing involves individuals 'reflecting on experiences by taking a step back and envisioning themselves from a vantage point of a distant observer' (Porter et al. 2022b, pp. 531–532). Distancing can be accomplished by thinking of a situation from the vantage point of a 'fly on a wall' or by asking someone to take the perspective of an exemplar, like children being asked to think about a decision based on what the superhero Batman would do (White & Carlson 2016). Studies document that self-distancing can help individuals overcome cognitive biases. For instance, Sun et al. (2018) examined the difference between having research participants think of lotteries with different probabilities and pay-offs from a self-immersive and from a self-distant perspective. The researchers did so to see whether the latter perspective lessened the research participants' likelihood of over-weighting high probabilities and under-weighting low probabilities (i.e., the probability-weighting bias). The expected effect of self-distancing was found: participants who adopted a self-distancing perspective were less prone to the probability-weighting bias, meaning that their judgements of the lotteries were not skewed due to the lower salience of small probabilities and higher salience of large probabilities (Sun et al. 2018). A general, exploratory theme in this research is how to foster objective reasoning, often about issues, experiences or topics that create emotional or cognitive challenges for the individual doing the reasoning (e.g., see Kross & Ayduk 2017).

A second theme identified by work on intellectual humility concerns humans' generally poor ability to assess their own knowledge, even among experts (e.g., Fisher & Keil 2016, Fonseca et al. 2023). Work in line with this theme has identified the way in which asking individuals to either write out or consider a step-by-step causal explanation of how an object or topic works can help temper their self-reported understanding of the object or topic (Porter et al. 2022b). This can create several potential benefits. Fernbach et al. (2013) found that individuals asked to provide a mechanistic causal explanation for certain policies (e.g., a cap-and-trade system) generally tempered their pre-explanation claims of knowledge about the policies. Requesting a causal explanation, the work suggests, helps individuals realize they know less than they thought, possibly changing their mindset away from a biased or sometimes teleological explanation of the matter in question (Kelemen et al. 2013). This main finding has been replicated by Crawford and Ruscio (2021). Other studies have shown that requesting a complete causal account may not even be needed to have individuals adjust their subjective assessments of their understanding. Johnson et al. (2016) showed that asking research participants to reflect on their ability to generate a step-by-step explanation of an object had the effect of efficiently (i.e., taking less time than required for a written explanation) reducing their overestimation of their subjective understanding.

## Towards the application of intellectual humility in conservation decision-making

Turning to conservation and questions of uncertainty, we can see benefits of using the ideas of self-distancing and causal explanation elicitations to inform approaches to fostering intellectual humility within conservation science and practice. Intellectual humility could be usefully seen as an aid for participants in conservation decision-making to recalibrate their own knowledge of the complex and often uncertain causal mechanisms that connect science to effective conservation outcomes. Perhaps more importantly, these ideas for how intellectual humility is incorporated may deepen existing understandings of why some forms of conservation decision-making work and how they may be able to work even more effectively to prevent unintended and unanticipated consequences. Here we provide examples from emerging approaches to support our proposal.

Structured decision-support tools and frameworks place considerable emphasis on the need for causal thinking and transparency about the way in which conservation interventions are expected to achieve outcomes and under what conditions, what their costs and benefits are and how they compare to other alternatives (Gregory et al. 2012, Bower et al. 2018). Innovative providers of decision support have also proposed ways of co-creating these frameworks and evidence-generating processes to help pluralize the knowledge basis for decisions and the trust and buy-in for conservation interventions (Christie et al. 2022). Similarly, promising tools such as value-of-information analysis and decision-facilitation techniques are being developed to aid in managing or mitigating uncertainty (Langford et al. 2009). Moore et al. (2012) use both of these tools in their management case study in alpine Australia of the grey sallow willow (*Salix cinerea*), an invasive, non-native species. Value-of-information analysis has become an accepted tool in conservation to determine whether more research will improve policy decisions. Such an analytical approach is used in considering whether collecting information to reduce uncertainty about a problem is worth doing (Bennett et al. 2018). Bennett et al. (2018) demonstrated the utility of this approach using case-simulated studies to choose among prospective habitat areas for single-species protection and to classify and manage multiple species under threat of becoming extinct.

The strategies of self-distancing and causal explanation elicitation have the potential to be grounded in a specific understanding of the limits to human knowledge. These strategies can help individuals be more reflective, self-aware of their limits and biases and open to other views when they engage in decision-making.

Miscalibration of knowledge can take various forms. Experts with high levels of knowledge may err by neglecting to consider new or external information; novices may underappreciate the complexity of a situation, sometimes because they perceive that others in their community hold an understanding on their behalf (Light & Fernbach 2020). Tackling these cognitive shortcomings directly seems imperative if decision-making is to avoid unanticipated and unintended consequences flowing from knowledge miscalibrations. Intellectual humility provides an underpinning for considering the failings of human cognition and how these can be managed in decision-making processes.

Indeed, researchers, managers and other actors in decision-making ought to be encouraged to consider questions of uncertainty from a self-distancing perspective so as to avoid self-focus, which

https://doi.org/10.1017/S0376892923000176 Published online by Cambridge University Press

might ossify prior expectations or lead to us falling prey to probability biases. This appears consistent with findings in conservation that suggest that bringing in a wider range of perspectives and concerns makes a difference (Failing et al. 2013). At the same time, it gives further conceptual and theoretical grounding as to what makes these processes effective in navigating conservation uncertainties. Drawing in people with dissimilar backgrounds necessitates taking a step back to articulate what might otherwise be assumed, such as what is uncertain, what the components of uncertainty being confronted are, which of these are not reducible through further research, the criteria for evaluating decision processes and outcomes and what outcomes from intervention are desirable. The adoption of self-distancing practices may, in this way, lessen the potential for unanticipated and unintended consequences.

Seeking the articulation of causal explanations has been demonstrated to help identify knowledge overestimation (Johnson et al. 2016, Light & Fernbach 2020). It also seems plausible that this strategy could be incorporated into structured processes that consider uncertainties across complex causal chains. This would help us to avoid possible unintended consequences stemming from an overestimation of knowledge and thus would be highly complementary to the proposed structured decision-making processes discussed above. Making causal complexity visible is consistent with calls for extensive transparency in decision-making processes regarding the uncertainties involved and how they might influence the outcome of a decision (McCarthy 2014). Full transparency requires communicating uncertainty and the basis for a chosen decision with relevant parties, even if the decision will not be embraced by all (Van der Bles et al. 2019). Transparency can help us to identify uncertainties outside of our own mental models, creating an enhanced opportunity for adaptative and iterative learning. Being transparent is to acknowledge the extent of learning still to be undertaken, a key component of intellectual humility. Providing transparency, as an intellectually humble approach, could become best practice in the reporting of science (Hoekstra & Vazire 2021).

## An agenda for intellectual humility in environmental conservation

Emerging insights on the nature, sources and consequences of intellectual humility offer an opportunity for conservation science to guide approaches to dealing with pervasive uncertainties in research and practice. Intellectual humility, we suggest, is salient to important aspects of uncertainty in conservation decisions. Most promisingly, constructive approaches to addressing uncertainty through intellectual humility are in accord with best practices for considering uncertainty in environmental conservation science and management. This includes the willingness to consider novel thinking and the perspectives of others and reflecting on conflicting information and perspectives.

To realize the potential of intellectual humility as an anchor for conservation decision-making, we call for greater attention to be given to how humility in practice may be identified and fostered (e.g., see Porter et al, 2022b). Decision-making processes need to take direct account of how they handle the cognitive limitations of the individuals involved. We foresee promising ideas emerging from practice and research informed by the body of work on intellectual humility, such as the strategic games approach proposed by Garcia et al. (2022) that seeks to better account for human agency and avoid stalling and unwelcome surprises during policy implementation.

Equally, we must remember that employing intellectual humility can only do so much and will not always lead to beneficial outcomes. Calls for additional research on many important conservation issues may be deliberate delay tactics by those with vested interests in maintaining the status quo (Ludwig et al. 1993). Thus, it is important to distinguish between situations where those who wish to derail conservation efforts cite the existence of uncertainty as a rationale for taking no action and situations where people are genuinely working towards solving a conservation problem of which uncertainty is a consideration (Ludwig et al. 1993). In the former circumstance, uncertainty is amplified to serve particular interests (van Asselt & Vos 2008), being used as a means to an end, such as stalling implementation, rather than addressing it conscientiously (Versluis et al. 2019). Consistent with concerns about the timeliness of action, work on intellectual humility clarifies that there are cases where humility can have ill effects. As Ballantyne (2023, p. 215) opines, 'Being intellectually humble could make us suckers', particularly when those making calls for humility have an incentive to delay action, as in the case of climate denialism (Oreskes & Conway 2011). Thus, it seems essential to focus on devising the contexts in which a focus on intellectual humility can help engender deeper understandings of conservation issues rather than buttressing calls for forestalling action.

It is helpful to remember that decisions, whether good or bad, are rarely final (Rytwinski et al. 2021). Most decision-making processes are iterative and, in due course, can be revisited. This may result from a change in government. Conservation problems, as Rittel and Webber (1973, p. 160) noted about social problems, 'are never solved. At best they are only re-solved – over and over again.' This is why a mindset of intellectual humility is important. When roadblocks appear in conservation decision-making, the helpful response is to acknowledge their complexity while maintaining progress, whether it is to work through or around them.

**Acknowledgements.** Thanks to Vivian Nguyen (Carleton University) for discussion that shaped the authors' thinking and to Gillian Zorn (Carleton University) for assisting with reference formatting. The authors also thank three anonymous reviewers for their comments.

**Financial support.** SM was supported by grants from the Fulbright Canada Program and the University of Nebraska Faculty Development Leave Program. GA, SJC, NY and JRB were supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) and Environment and Climate Change Canada. JCV was supported by the NSERC Discovery Program.

**Competing interests.** The authors declare none.

**Ethical standards.** None.

## References

Alblas E, van Zeben J (2023) 'Farming out' biodiversity: implementing EU nature law through agri-environmental schemes. *Earth System Governance* 17, 100180.

Ballantyne N (2023) Recent work on intellectual humility: a philosopher's perspective. *Journal of Positive Psychology* 18: 200–220.

Bennett JR, Maxwell SL, Martin AE, Chadès I, Fahrig L, Gilbert B (2018) When to monitor and when to act: value of information theory for multiple management units and limited budgets. *Journal of Applied Ecology* 55: 2102–2113.

Bird SC, Hodges KE (2017) Critical habitat designation for Canadian listed species: slow, biased, and incomplete. *Environmental Science Policy* 71: 1–8.

https://doi.org/10.1017/S0376892923000176 Published online by Cambridge University Press

Bower SD, Brownscombe JW, Birnie-Gauvin K, Ford MI, Moraga AD, Pusiak RJ, et al. (2018) Making tough choices: picking the appropriate conservation decision-making tool. *Conservation Letters* 11: e12418.

Campbell BM, Sayer JA, Walker B (2010) Navigating trade-offs: working for conservation and development outcomes. *Ecology and Society* 15: 16.

Christie AP, Downey H, Frick WF, Grainger M, O'Brien D, Tinsley-Marshall P, et al. (2022) A practical conservation tool to combine diverse types of evidence for transparent evidence-based decision-making. *Conservation Science and Practice* 4: e579.

Crawford JT, Ruscio J (2021) Asking people to explain complex policies does not increase political moderation: three preregistered failures to closely replicate Fernbach, Rogers, Fox, and Sloman's (2013) findings. *Psychological Science* 32: 611–621.

Douglas M, Wildavsky AB (1982) *Risk and Culture: An Essay on the Selection of Technical and Environmental Dangers*. Berkeley, CA, USA: University of California Press.

Failing L, Gregory R, Higgins P (2013) Science, uncertainty, and values in ecological restoration: a case study in structured decision-making and adaptive management. *Restoration Ecology* 21: 422–430.

Fatichi SS, Barbosa M, Caporali E, Silva ME (2009) Deterministic versus stochastic trends: detection and challenges. *Journal of Geophysical Research: Atmospheres* 114: D18121.

Fernbach PM, Rogers T, Fox CR, Sloman SA (2013) Political extremism is supported by an illusion of understanding. *Psychological Science* 24: 939–946.

Fisher M, Keil FC (2016) The curse of expertise: when more knowledge leads to miscalibrated explanatory insight. *Cognitive Science* 40: 1251–1269.

Folt CL, Chen CY, Moore MV, Burnaford J (1999) Synergism and antagonism among multiple stressors. *Limnology and Oceanography* 44: 864–877.

Fonseca C, Pettitt J, Woollard A, Rutherford A, Bickmore W, Ferguson-Smith A, Hurst LD (2023) People with more extreme attitudes towards science have self-confidence in their understanding of science, even if this is not justified. *PLoS Biology* 21: e3001915.

Gale A, Chapman J, White D, Ahluwalia P, Williamson A, Peacock K, et al. (2022) On embracing the concept of becoming environmental problem solvers: the trainee perspective on key elements of success, essential skills, and mindset. *Environmental Reviews* 30: 1–9.

Garcia CA, Savilaakso S, Verburg RW, Stoudmann N, Fernbach P, Sloman SA, et al. (2022) Strategy games to improve environmental policymaking. *Nature Sustainability* 5: 464–471.

Gregory R, Failing L, Harstone M, Long G, McDaniels T, Ohlson D (2012) *Structured Decision Making: A Practical Guide to Environmental Management Choices*. Chichester, UK: Wiley-Blackwell.

Henderson J (2018) Managing uncertainty for preventive conservation. *Studies in Conservation* 63: 108–112.

Hirsch PD, Adams WM, Brosius JP, Zia A, Bariola N, Dammert JL (2011) Acknowledging conservation trade-offs and embracing complexity. *Conservation Biology* 25: 259–264.

Hoekstra R, Vazire S (2021) Aspiring to greater intellectual humility in science. *Nature Human Behaviour* 5: 1602–1607.

Johnson DR, Murphy MP, Messer RM (2016) Reflecting on explanatory ability: a mechanism for detecting gaps in causal knowledge. *Journal of Experimental Psychology: General* 145: 573.

Keith DA, Martin TG, McDonald-Madden E, Walters C (2011) Uncertainty and adaptive management for biodiversity conservation. *Biological Conservation* 144: 1175–1178.

Kelemen D, Rottman J, Seston R (2013) Professional physical scientists display tenacious teleological tendencies: purpose-based reasoning as a cognitive default. *Journal of Experimental Psychology* 142: 1074.

Knight AT, Cook CN, Redford KH, Biggs D, Ortega-Argueta RCA, Norman CD et al. (2019) Improving conservation practice with principles and tools from systems thinking and evaluation. *Sustainability Science* 14: 1531–1548.

Kremer JN (1983) Ecological implications of parameter uncertainty in stochastic simulation. *Ecological Modelling* 18: 187–207.

Kross E, Ayduk O (2017) Self-distancing: theory, research, and current directions. In JM Olson (ed.), *Advances in Experimental Social Psychology* (vol. 55, pp. 81–136). Amsterdam, The Netherlands: Elsevier.

Langford WT, Gordon A, Bastin L (2009) When do conservation planning methods deliver? Quantifying the consequences of uncertainty. *Ecological Informatics* 4: 123–135.

Leman J, Kurinec C, Rowatt W (2023) Overconfident and unaware: intellectual humility and the calibration of metacognition. *Journal of Positive Psychology* 18: 178–196.

Light N, Fernbach P (2020) The role of knowledge calibration in intellectual humility. In M Alfano, MP Lynch, A Tanesini (eds), *The Routledge Handbook of Philosophy of Humility* (pp. 411–424). Abingdon, UK: Routledge.

Low B, Costanza R, Ostrom E, Wilson J, Simon CP (1999) Human–ecosystem interactions: a dynamic integrated model. *Ecological Economics* 31: 227–242.

Ludwig D, Hilborn R, Waters C (1993) Uncertainty, resource exploitation, and conservation: lessons from history. *Science* 260: 17–36.

McCarthy MA (2014) Contending with uncertainty in conservation management decisions. *Annals of the New York Academy of Sciences* 1322: 77–91.

Milner-Gulland EJ, Shea K (2017) Embracing uncertainty in applied ecology. *Journal of Applied Ecology* 54: 2063–2068.

Moore JL, Runge MC (2012) Combining structured decision making and value-of-information analyses to identify robust management strategies. *Conservation Biology* 26: 810–820.

Oreskes N, Conway EM (2011) *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. New York, NY, USA: Bloomsbury Publishing USA.

Pearson DE, Clark TJ, Hahn PG (2022) Evaluating unintended consequences of intentional species introductions and eradications for improved conservation management. *Conservation Biology* 36: e13734.

Porter T, Baldwin CR, Warren MT, Murray ED, Cotton Bronk K, Forgeard MJ, et al. (2022a) Clarifying the content of intellectual humility: a systematic review and integrative framework. *Journal of Personality Assessment* 104: 573–585.

Porter T, Elnakouri A, Meyers EA, Shibayama T, Jayawickreme E, Grossmann I (2022b) Predictors and consequences of intellectual humility. *Nature Reviews Psychology* 1: 524–536.

Regan HM, Colyvan M, Burgman MA (2002) A taxonomy and treatment of uncertainty for ecology and conservation biology. *Ecological Applications* 12: 618–628.

Rice WS (2022) Identifying and developing effective post-2020 conservation bridging leaders. *Conservation Biology* 36: e13980.

Rittel HJW, Webber M (1973) Dilemmas in a general theory of planning. *Policy Sciences* 4: 155–169.

Runge MC, Converse SJ, Lyons JE (2011) Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. *Biological Conservation* 144: 1214–1223.

Rytwinski T, Cooke SJ, Taylor JJ, Roche DG, Smith PA, Mitchell GW, et al. (2021) Acting in the face of evidentiary ambiguity, bias, and absence arising from systematic reviews in applied environmental science. *Science of the Total Environment* 775: 145122.

Schultz PW (2011) Conservation means behavior. *Conservation Biology* 25: 1080–1083.

Scoones I (2019) *What Is Uncertainty and Why Does It Matter? STEPS Working Paper 105*. Brighton, UK: STEPS Centre.

Slovic P (1987) Perception of risk. *Science* 236: 280–285.

Sun Q, Zhang H, Sai L, Hu F (2018) Self-distancing reduces probability-weighting biases. *Frontiers in Psychology* 9: 611.

Syrett M, Devine M (2012) *Managing Uncertainty: Strategies for Surviving and Thriving in Turbulent Times*. London, UK: Profile Books.

Tangney JP (2000) Humility: theoretical perspectives, empirical findings and directions for future research. *Journal of Social and Clinical Psychology* 19: 70–82.

Tangney JP (2009) Humility. In CR Snyder, SJ Lopez (eds), *Oxford Handbook of Positive Psychology* (pp. 483–490). Oxford, UK: Oxford University Press.

van Asselt MBA, Vos E (2008) Wrestling with uncertain risks: EU regulation of GMOs and the uncertainty paradox. *Journal of Risk Research* 11: 281–300.

Van der Bles AM, Van Der Linden S, Freeman AL, Mitchell J, Galvao AB, Zaval L, Spiegelhalter DJ (2019) Communicating uncertainty about facts, numbers and science. *Royal Society Open Science* 6: 181870.

https://doi.org/10.1017/S0376892923000176 Published online by Cambridge University Press

Versluis E, van Asselt M, Kim J (2019) The multilevel regulation of complex policy problems: uncertainty and the swine flu pandemic. *European Policy Analysis* 5: 80–98.

Walker WE, Harremoës P, Rotmans J, van der Sluijs JP, van Asselt MBA, Janssen P, Krayer von Krauss MP (2003) Defining uncertainty: a conceptual basis for uncertainty management in model-based decision support. *Integrated Assessment* 4: 5–17.

Whitcomb D, Battaly H, Baehr J, Howard-Snyder D (2017) Intellectual humility: owning our limitations. *Philosophy and Phenomenological Research* XCIV: 509–539.

White RE, Carlson SM (2016) What would Batman do? Self-distancing improves executive function in young children. *Developmental Science* 19: 419–426.

Young N, Corriveau M, Nguyen VM, Cooke SJ, Hinch SG (2016) How do potential knowledge users evaluate new claims about a contested resource? Problems of power and politics in knowledge exchange and mobilization. *Journal of Environmental Management* 184: 380–388.

https://doi.org/10.1017/S0376892923000176 Published online by Cambridge University Press