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Thinking of Biology

More reason for humility in our relationships with ecological communities

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Abstract

Many public decisions about the environment seem infused with a worldview that supposes nature is well understood as a machine and that the key purpose of science is the discovery of its rules to then control nature for the betterment of humanity. That nature-as-machine worldview leads to damaging overconfidence in forecasting ecological outcomes. A competing worldview is that nature is better understood to unfold like human history—explainable but critically and inherently unpredictable because of the important influence of historically contingent events. Recent analysis offers compelling support for this idea. This article explores a demanding consequence of such findings—namely, that those involved—directly and indirectly—with environmental decision-making should strive to relax the influence of the nature-as-machine worldview on environmental decisions, including difficult-to-identify influences that have resulted from centuries of this worldview's normalization. This striving includes analyzing decisions about the environment in terms of humility and favoring humbler decisions.

Keywords: consequentialism, forecasting, historical contingency, philosophy of science, uncertainty

For centuries, an essential belief in Western thought has been that nature is much like a machine and is driven by rules to be discovered by scientists (Shapin 1998). According to Enlightenment thinkers, the reward for such discovery is better control of nature for the betterment of humankind (Liebeskind 2023). This is certainly not the view of every scientist or every user of science (such as decision-makers and engineers) but does seem to be a worldview with significant influence on many public decisions. This worldview also has a mixed record. Knowing the rules by which antibiotics control infection has been great for health. Less good has come from overusing antibiotics to control the infections that run rampant when we raise livestock in overcrowded conditions.

Controlling nature depends on being able to forecast the consequences of manipulations of nature. As such, this nature-as-machine belief fosters a strong connection between explanation and prediction, especially forecasts—as opposed to hindcasts of previously observed states—based on theory representing the underlying rules of nature. Ultimately, the degree to which one can claim to have developed a scientific explanation is importantly dependent on the accuracy of theory-based predictions for the next observation of that phenomenon (box 1). By this view of nature, surprises are an anathema to science, inasmuch as they suggest where scientists need to work harder to better understand the rules of nature.

Another anathema to the nature-as-machine belief is the millennia-old belief that the world is best understood as being essentially shaped by historical contingencies—a series of randomly timed, disparate events of deep consequence. By this belief, the world unfolds much like human history, such as when one claims, for example, that the history of nineteenth century Europe was essentially shaped by Napoleon's loss in the battle of Waterloo. In nature, the importance of historical contingency is illustrated by the asteroid that struck Earth 66 million years ago, which led to the extinction of the dinosaurs, without which the evolutionary rise of mammals would not have occurred. Both examples—Waterloo and the asteroid—are accidents of history in the sense of not being forecastable from an understanding of logical necessities or the laws of nature.

By this nature-as-history belief, it seems inevitable that surprises in the natural world would be common and that our ability to forecast what happens next would be inherently more limited than we typically suppose. By this belief, surprises are not a concession to having failed to find the essential rules of nature. Rather, surprises are the discovery of nature's deep, underlying way.

The importance of historical contingency in evolutionary dynamics that unfold on geologic scales of time has been debated (e.g., Gould 1989, Morris 1998), but much less so in the domains of ecology or on time scales most relevant to conservation. However, in a recent paper, we developed ideas about historical contingencies into a formal, quantitatively testable hypothesis for populations (Hoy et al. 2024a). In that same paper, we operationalized and tested that hypothesis by demonstrating how a series of historically contingent events led to impressive explanatory power for half a century of predation dynamics between the wolf and moose populations of Isle Royale National Park. The formal hypothesis and its operationalization are summarized in box 2. The analysis is noteworthy for having discovered a way to quantify the explanatory power of ecological histories marked by events that appear to have triggered subsequent dynamics. As a result, discourse about nature as history, as opposed to nature as a machine, becomes a little less metaphysical and a little more empirical.

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Box 1. Connection between prediction and explanation, illustrated with familiar example.

Ecologists have found the number of species inhabiting islands to vary among islands. That simple idea provides an essential and easy-to-overlook ingredient—variation. A scientist can get excited about variation in just about anything that can be measured. In this case, we're looking at variation in biodiversity. The scientific goal is to explain the variation: Why do different islands have different numbers of species? More precisely, ecologists noticed biodiversity tends to increase in a particular way with island area. That led other ecologists to develop equations that could predict biodiversity given an island's area. These equations were based on mechanisms thought to govern processes that might determine island biodiversity—especially the notion that extinction should be more common on small islands, and recolonization should be more common on islands that are closer to other islands. Ultimately, the equation developed to predict how biodiversity (S) increases with island area (A) was $S = aA^b$ (MacArthur and Wilson 1967), and its predictions align closely with observations from many islands. For emphasis, $S = aA^b$ does not merely provide a good description of already observed data; it has also been shown to be a reliable basis for forecasting diversity on subsequently observed islands. Scientists say that a formula and its supporting theory *explain* the relationship between biodiversity and island area to the extent that is it forecastable by that theory-based formula. The special value placed on forecasts extrapolated over time is also indicated, for example, by the importance assigned to cross-validation as a broadly valued statistical technique (e.g., Hoy et al. 2024a).

Finally, important differences arise when explanation is based on experimental versus nonexperimental data. That distinction does not alter the salient point, which is that theory-based predictions play an important role in explaining nature.

Details of the analysis by Hoy and colleagues (2024a) also offer reason to think that the historical contingency hypothesis (HCH) is applicable to many populations. Those details pertain to the HCH's relationship to other ecological phenomena that appear to be common—namely, ecological surprises (Doak et al. 2008), alternative stable states (Beisner et al. 2003), and the nonstationarity and reddened spectra of ecological time series (Ariño and Pimm 1995).

The analysis presented in Hoy and colleagues (2024a) also shows that the nature-as-machine and nature-as-history worldviews can coexist. For example, embracing a nature-as-history worldview would *not* be a call to dismiss the notion that nature has rules to be discovered or that such discoveries are unimportant forms of scientific explanation. But acknowledging a nature-as-history worldview would demand that decision-making in conservation take account of patterns in nature that science can reliably forecast, while also curbing the overconfidence that seems to come with an unduly tight embrace of the nature-as-machine worldview. We explain and describe elements of these more balanced decision-making processes beginning in the next section.

Applied ethics

Applied ethics, as an academic pursuit, is largely focused on the analysis of propositions that can be expressed using the phrase *We should*, as is illustrated by these examples: *We should conserve this endangered population by killing individuals of an overabundant species (because they are preying on or competing with the endangered population). We should conserve this biodiverse area by restricting human inhabitants' use of that area.* Those examples also indicate the inevitable connection between conservation decisions and applied ethics.

In Western culture, academic ethics is characterized by several alternative frameworks. The frameworks that receive the most attention are consequentialism and its foil, deontology. Deontology supposes that an action is right if it honors principles to which we are duty bound. Consequentialism supposes that the most appropriate actions are those resulting in the best consequences. In a nontechnical, albeit useful, sense the two frameworks are crudely distinguished by their disposition toward the aphorism, the ends justify the mean. Consequentialism gravitates toward that aphorism; deontology does not. These frameworks can also be crudely distinguished by their disposition toward white lies. A deontologist is liable to avoid white lies to uphold a principled duty to be honest. A consequentialist would decide by assessing the consequences of telling the white lie. For an example that highlights the distinction between these frameworks for a conservation-relevant issue, see box 3.

In private and public life, decisions lean to varying degrees on consequentialism and deontology. Nevertheless, consequentialism is arguably the dominant ethical framework for formal decision-making and policy development (MacIntyre 1981), especially in matters pertaining to the environment (Tanner 2009, Holland 2013). Consequentialism's dominance is likely due, in part, to two elements: First, consequentialism's focus on evaluating the expected costs and benefits of a decision can seem well aligned with technocracies that express favor for science-based decisions (e.g., Kuhlmann et al. 2022) and with the branch of decision theory focused on quantitative methods for determining optimal decisions (Hemming et al. 2022). Second, disagreement among the stakeholders about what duties or principles should guide policy often seems entrenched and unyielding to negotiation, whereas compromise over the consequences of a particular policy proposal can seem more promising to negotiate (e.g., Madden and McQuinn 2014).

Although these features of consequentialism may seem attractive, it is important to also consider two potential limitations of consequentialism. First, consequentialism would seem to be limited to the extent that decision-makers are limited in their capacity to appropriately weigh the costs and benefits of all those affected. The second limitation is decision-makers' limited capacity to make adequate forecasts of the consequences of a proposed policy.

The importance of the forecast limitation in the context of natural resource management is well illustrated, for example, by the case detailed in Rapp and Nelson (2024). The broad extent of the costs–benefits limitation is indicated by the frequency of environmental injustices, whereby certain human groups (typically those with less political power) are treated unfairly in environmental decision-making. Examples include the tendency for poor people and racial minorities to be exposed to more pollution (Mohai et al. 2009) and the forcible removal of Indigenous people from their homelands to establish protected areas for conservation (Williams 2024). The costs–benefits limitation may be even more severe when considering decisions that involve the consequences for human and nonhuman stakeholders. For example,

Box 2. Explanation via historical contingencies.

Predation dynamics for the wolf and moose populations in Isle Royale have been marked by a series of historically contingent events, each seeming to trigger a period of new dynamics. In the early 1980s a newly evolved disease struck the wolf population. Let's call that disease outbreak, event A, whose legacy was a long period of depressed wolf abundance and rising moose abundance (figure 1).

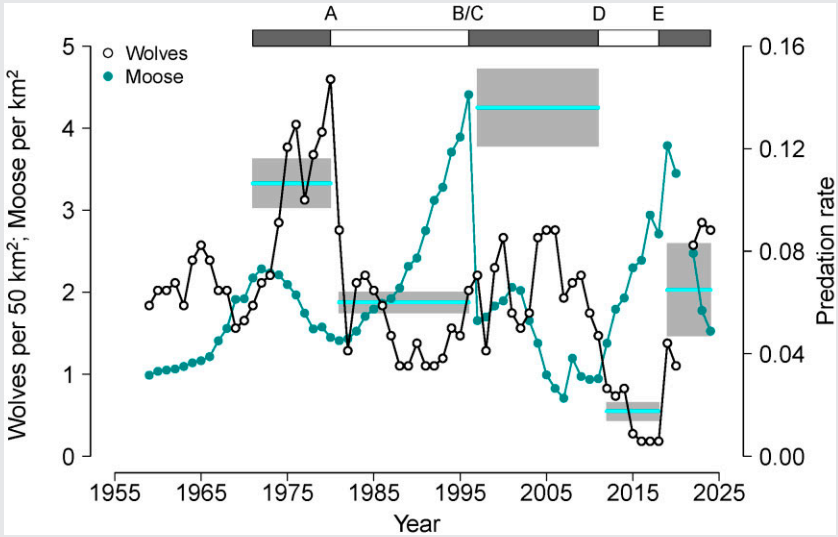

Figure 1. Densities of wolves and moose in Isle Royale National Park, 1958–2024 (left ordinate). The horizonal bar at the top divides the time series into segments whose boundaries are marked by historically contingent events (a–e), which are described in box 2. The grey boxes with blue lines represent predation rate for each segment of the time series. The blue lines are averages and the gray boxes are standard errors (right ordinate). Hoy and colleagues (2024a) demonstrated how a statistical model of predation rate that takes account only of these historically contingent events is not outperformed by traditional approaches to modeling predation rate.

In 1996, the most severe winter ever recorded in the region struck. That winter coincided with the highest density of moose observed on Isle Royale. The moose population crashed. Let's call that winter, event B.

A year later, a wolf emigrated to Isle Royale by crossing an ice bridge—the only way a wolf can cross the channel between Isle Royale and the mainland. The immigrant revealed that the wolves had been suffering from severe inbreeding depression, represented a powerful genetic rescue and improved the wolf population's fitness, and led to realizing that gene flow had occurred occasionally throughout the history of Isle Royale wolves. The immigration event (event C) upset assumptions that had been firmly and widely held for decades—namely, that the wolf population was genetically isolated and not suffering from inbreeding depression.

Between 2007 and 2010, the beneficial effects of genetic rescue dissolved, inbreeding depression resumed, and canine parvovirus reappeared after a 17-year (four generation) absence. We'll say that convergence of events is event D, after which the wolf population dwindled to two, highly inbred wolves who never produced surviving offspring.

As the wolf population headed towards extinction, moose abundance more than tripled, and moose browsing severely impacted the island's vegetation. Those circumstances led the National Park Service (NPS) to restore wolf predation by translocating 19 wolves to Isle Royale in 2018 and 2019. This anthropogenic intervention (event E) was surprising, because traditional NPS policy and most of the decision-making process pointed toward the NPS not intervening. Following the translocations, wolf abundance steadily increased and moose abundance declined.

Those five events represent a series of historically contingent events. The historical contingency hypothesis (HCH) states that population-level phenomena are well explained by a series of historically contingent events—that is, a series of random events characterized by significant legacy effects that are comparable in length to the waiting time between such events and the disparate nature of individual events in the series. Those five events on Isle Royale were all recognized as major events in the chronology of wolves and moose on being observed and long before the HCH was formulated. In other words, these events were not selected in an ad hoc manner for the purpose of testing the HCH with the statistical model described below.

(*Continued*)

Box 2. Explanation via historical contingencies.

We translated the preceding historical narrative into a statistical model to explain interannual fluctuations in predation rate, which is a statistic that synthesizes the most important elements of predation—that is, prey abundance, predator abundance, and the per capita rate at which wolves kill prey. We built this model by dividing the time series into segments defined by events A through E. Then we built a linear model consisting of 4 intercepts and indicator variables such that the variance in predation rate is explained simply by noting which segment of the time series is being referred to (figure 1). This model explains approximately 56% of the variance in predation rate. To better understand this model's performance, which represents the HCH, we built a suite of competing models—some based on *a priori* theory and others built by data dredging. No model had more explanatory power than the historical contingency model.

Box 3. Illustrating ethical frameworks in conservation.

In southern British Columbia there is an ongoing, controversial effort to protect endangered caribou populations by killing wolves, which are viewed as overabundant (Cornwall 2024). Wolves are overabundant because moose are overabundant. Moose are overabundant because government and industry log the forest landscape in a manner that leads to overabundant moose. The logging is motivated by the search for more fossil fuels. Finally, there is concern that killing wolves is insufficient for protecting caribou, and the other actions required to protect caribou are not being taken. An argument representing a reason to kill the wolves is:

P1. Caribou populations are valuable to ecosystem health and possess intrinsic value.
P2. Individual wolves have intrinsic value (and therefore shouldn't be killed without good reason).
P3. Protecting caribou is a good reason to kill wolves.
C. We should kill wolves for the purpose of conserving caribou.

This is merely a heuristic argument and not a complete assessment of the issue. Seeing the point of this argument begins by knowing that an argument is unsound if any of its premises are inappropriate. Furthermore, people who think killing wolves to protect caribou is appropriate would likely be deeply impressed by the grave consequences of losing caribou. But people who think it is inappropriate would likely be more deeply impressed by deontological thinking—that is, the wrongness of killing sentient creatures who are not culpable for the problem, especially given that humans are not ceasing to mitigate the ultimate cause of wolf overabundance or taking the other necessary steps to protect caribou. (For more on the use of arguments to evaluate ethical ideas in conservation, see Vucetich et al. 2019.)

Vucetich and colleagues (2019) explained the near impossibility of accurately taking account of harms to individual lions that are trophy hunted and the possible benefits to lion populations as a result of trophy hunting while also accurately taking account of the harms and benefits to the disparate groups of humans with a stake in decisions about lion conservation.

It should be noted that consequentialism and deontology are centuries-old ideas. For every defense and for every criticism of each framework, there are rejoinders and rejoinders to those rejoinders. In the present article, we describe these general frameworks just enough to provide a reasonable understanding of the specific points we are aiming to make. It may also be useful to know that we are pluralists with respect to ethical frameworks. That is, we believe each framework mentioned in this article has its own distinctive set of strengths and weaknesses, and understanding any particular, complicated, real-world decision can be aided by drawing on more than one framework. We also think that wise application of different ethical frameworks often leads to the same good decision (Parfitt 2011).

Overconfidence

Recall that key elements of the nature-as-machine worldview are that nature is best understood to be like a machine, that an essential purpose of science is discovery of the machine's rules so that it can be manipulated for—as Francis Bacon put it—"the relief of man's estate" (Bacon 1605), and that the capacity to forecast future states of nature is a basic indicator of having discovered those rules. When that worldview is taken too far—in the sense of supposing, even implicitly, an exaggerated ability to forecast—that circumstance might be considered an instance of overconfidence.

Overconfidence among experts is also the subject of formal inquiry by psychologists. The lessons from that research are reflected, in part, by this summarization of Kahneman's (2011) treatment of the subject: Consider a sample of financial experts who forecast the annual growth of some market. They'd produce a range of forecasts: 2% growth, 3% contraction, etc. Now imagine waiting a year and comparing those forecasts to the actual changes. The uninteresting result would be that these forecasts would run a gamut of accuracies. The interesting result rises from also having queried these experts about the range of values within which they are 80% confident the market's actual change will lie. For example, an expert might be 80% confident that the market's change will be between –4% and 2%. If the actual change fell outside that range, then the expert should be surprised. A group of experts that accurately understood the limits of their expertise would be surprised about 20% (=1– 0.80) of the time. In reality, research indicates that financial experts are surprised about 67% of the time (Kahneman 2011, p. 262). The frequency for that kind of surprise represents an impressive level of overconfidence.

Studies like this have been conducted for a range of expertise types (e.g., medical doctors, law enforcement officers, engineers; Sanchez and Dunning 2023), including ecologists (McBride et al. 2012). Others have provided additional reasoning to think overconfidence is a concern in ecology (Johnson and Levin 2009, Drescher et al. 2013, Iftekhar and Pannell 2015).

Among the possible reasons for overconfidence among experts this that they tend to operate in environments where they are expected or rewarded for being more confident than is otherwise justified (Kahneman 2011). Similarly, an expert who believes their scientific understanding should influence a decision may also be more confident than is otherwise justified, and decision-makers may respond accordingly to that display of confidence.

Other psychological research indicates that when science is reported in an accessible manner, the effect on nonexperts can be overconfidence about the science and their understanding of it (e.g., Fradera 2017, Scharrer et al. 2017). This is pertinent because decision-makers are often not experts in the science on which their decisions depend.

Beyond the existence of overconfidence and its possible causes, others have argued that overconfidence exists enough in public decisions about human–nature relationships to be seriously damaging. A particularly important example is Holling and Meffe's highly cited 1996 article, entitled, "Command and control and the pathology of natural resource management," which states, "a common theme of many resource-management efforts is to reduce natural bounds of variation in ecological systems to make them more predictable, and thus more reliable, for human needs… the purpose is to turn an unpredictable and 'inefficient' natural system into one that produces products in a predictable and economically efficient way… When unanticipated environmental problems then arise, the a priori expectation of certainty is not met and results in surprise and crisis… Such crises and surprises, we argue here, are the inevitable consequences of a command-and-control approach to renewable resource management, where it is (implicitly or explicitly) believed that humans can select one component of a self-sustaining natural system and change it to a fundamentally different configuration in which the adjusted system remains in that new configuration indefinitely without other, related changes in the larger system."

Holling and Meffe (1996) provided a number of specific examples of this concern. They are far from alone in expressing such concerns (e.g., Nelson and Bledsoe 2020, Sadler-Smith and Akstinaite 2021).

Recall that the nature-as-history worldview and the empirical evidence for that worldview brought by Hoy and colleagues' (2024a) assessment of the HCH provide an explanation for why ecologists are so poor at making forecasts and so commonly surprised. Those circumstances—impoverished forecasts and frequent surprises—are also explained by the nature-as-machine view of the world. The explanation is that nature's rules are nonlinear (Clark and Luis 2020) and multicausal (Peterson et al. 2014), and dynamics rising from such rules are notoriously difficult to forecast. As such, a failure to accurately forecast is not evidence of an inherent inability to forecast; rather, it is inspiration for scientists to work harder at making better forecasts through better data collection, better experimentation, and better mathematical modeling (e.g., Hsieh et al. 2008, Johnson et al. 2021, Ye et al. 2023). Although it is important that scientists acknowledge that nonlinear systems are really hard to forecast, that acknowledgement seems insufficient for mitigating the kind of overconfidence that others have argued to be so damaging.

Finally, some readers will be concerned that it is wrong to suppose that overconfidence is an important "pathology" for natural resource management. We think those readers would want us to, at least, indicate that the reasoning that unfolds in the remainder of this article is premised on the assumption that the overconfidence to which we have been referring is a problem.

Humility

If overconfident forecasting is the vice to mitigate, an antidote would seem to be the virtue of humility. Others have written about how and why public decisions about human–nature relationships should be humbler (e.g., Weinstein 2015, Koch 2020, Hoekstra and Vazire 2021, Porensky 2021, Sadler-Smith and Akstinaite 2021, Gould et al. 2023). The aim of the essay is narrow in the sense of providing another important reason to do so—a reason rising from the HCH.

The HCH provides scientific reason to favor decisions about the environment that better embody the virtue of humility. In particular and as was indicated above, the HCH provides robust scientific explanations without being so dependent on providing an accurate forecast as evidence for having done so. In other words, the HCH allows ecologists to be good at what they do (explain natural phenomena) without being tempted to overestimate abilities to forecast. The HCH also explains why ecological surprises are common and focusses attention on the inherent limitations of forecasting. (See box 2 and Hoy et al. 2024a for additional explanation.)

If scientific knowledge favors the careful application of humility (or any other virtue for that matter) in environmental decision-making, then how exactly can that be accomplished in a robust and reliable manner? The question is important because virtues like humility can seem too subjective or imprecise to be an important basis for public decision-making.

A useful answer to that question begins by considering virtue ethics, which is a well-developed ethical framework—on par with consequentialism and deontology—with documented roots in Western and Eastern thought (Hursthouse and Pettigrove 2023). According to an important formulation of virtue ethics, virtues are a bridge between how we aspire to be and how we are. The idea, more precisely, is that our behaviors are shaped by the virtues we embrace, and the virtues we embrace depend on the purpose in life that we set for ourselves (MacIntrye 1981):

$$\text{purpose} \rightarrow \text{virtue} \rightarrow \text{behaviors and decisions.}$$

This formulation of virtue ethics may be connected to other formulations of virtue ethics by substituting the connection between purpose and virtue with the question, "What kind of a people do we want to be?" The answer to that question guides one toward the virtues they should practice. For example, Aristotle thought an especially important purpose in life is to be a good citizen. The virtues that Aristotle thought would lead to behaving like a good citizen included, honesty, forbearance, and magnanimity.

An often raised but exaggerated concern with virtue ethics is that it sometimes seems unable to provide sufficiently precise guidance for what decision to make in any particular case (Athanassoulis 2024). A first step in navigating this concern is to know that humility is more than admitting a limitation but otherwise making the same decision that would be made without any such admission. To further illustrate the prescriptive power of humility, consider two examples. These examples relate to the purpose–virtue–decision conceptualization of virtue ethics. The first example focuses on purpose and the second on decisions.

Consider *sustainability*, which is well characterized as "meeting human needs in a socially just manner without depriving ecosystems of their health." Depending on how critical normative terms such as *human needs* and *ecosystem health* are defined, *sustainability* could mean anything from "exploit as much as desired without infringing on future ability to exploit as much as desired" to "exploit as little as necessary to maintain a meaningful life" (Vucetich and Nelson 2010). Those divergent understandings of sustainability represent the essence of two possible purposes in life. The latter purpose would seem to be humbler—and the former purpose, not so much—if there are concerns about misforecasting the consequences of exploiting "as much as desired" (as opposed to "as little as necessary") or about some groups (including nonhumans) not being able to exploit as much as they'd desire because doing so has been precluded by others who are exploiting as much as they'd desire. The humbler purpose would also unambiguously exclude a wide swath of behaviors and decisions. The difficulty that humility presents is less how to analyze it and more deciding whether to genuinely aspire to its prescriptions.

Humility is also readily analyzed for more specific conservation decisions. Take, for example, the wolf–caribou example described in box 3. And consider that humility is true self-knowledge, especially with respect to one's faults and errors (e.g., Hamman 2021). As such, it would seem not humble for a group of people to sanction killing wolves for the purpose of conserving caribou if those people are at fault for continuing to drive caribou to extinction and do so without atonement.

Humility is also knowing where one ranks among others (e.g., Cablson 1944). As such, it seems not humble for a group of humans to place themselves above and in control of nonhumans, given the kinship that Darwin discovered between humans and nonhumans. Not placing ourselves above nonhumans would seem to require decision-making that accounts for the result of a thought experiment that involves asking the wolf and caribou for their views on the matter. This thought experiment is required for reasons similar to those offered for demanding application of John Rawl's (1971) veil of ignorance, Adam Smith's ([1759] 2001) impartial spectator, and Immauel Kant's ([1785] 2005) procedure for discovering categorical imperatives. Each of those ideas is a kind of thought experiment that is considered essential for just decision-making (Freeman 2016) and similar to the one proposed for considering wolves and caribou. Many other scholars have argued for the appropriateness of applying such thought experiments to cases involving humans and nonhumans (Vucetich et al. 2018 and the references therein).

A critic might offer good reason to object to those particular applications of humility. And we might be able to provide rejoinders. If we did, then we would be analyzing a decision through the lens of humility. And that is our point: Humility can be robustly analyzed for real conservation decisions. Furthermore, a critic might agree that humility can be analyzed but might think that the decision resulting from such an analysis is politically untenable. The response to that concern is, again, that the difficulty is not in analyzing humility; the difficulty is in deciding to embrace humility.

Additional insight about the application of humility to public decision-making may be had by considering recent policies mandating that federal governments take substantive account of Indigenous knowledge when making policy decisions. Such policies have been enacted in the United States, Canada, New Zealand, and Australia. This is relevant because others have pointed out how elements of at least some Indigenous knowledges seem well characterized by the ideas that characterize virtue ethics (e.g., Perrett and Patterson 1991, Alterado et al. 2023). Furthermore, it seems that humility is a virtue that is emphasized by at least some Indigenous knowledges (Verbos and Humphries 2014, Topkok 2015, Whyte et al. 2016, Bishop 2023).

Those circumstances are salient in this way. It is appropriate to acknowledge the unfamiliarity of making public decisions that are more deeply imbued with virtues such as humility. But that unfamiliarity does not absolve legal or moral obligations to do so. Furthermore, this unfamiliarity should be contextualized: There was a time, not long ago, when policy decisions by the executive branches of government neglected broader stakeholder engagement and knowledge from various human dimensions of conservation. When confronted with mandates to do better, decision-makers were unfamiliar with how to do so. But they are now making substantive progress in learning how to do so (Bennett et al. 2017).

Those circumstance about unfamiliarity apply to the incorporation of virtues, such as humility, into the decision-making processes. In other words, not knowing how to articulate and analyze decisions on the basis of humility is not an indication that it cannot be done. Because this learning may be difficult, it is unlikely to occur without sufficient motivation. That motivation is, we hope, supplied to some worthwhile degree by this article.

Environmental decision-makers may find worthwhile insight by consulting other institutions that have begun to explore the application of virtues to decision-making (e.g., Vizcarrondo 2012, Sison et al. 2017, George and Rose 2023). Practical insight may also be found in considering how tribal governance imbued its decisions with virtue (Marchand et al. 2020). Because it bears repeating, the analysis of humility in decision-making is likely not as difficult as deciding to embrace humility in our relationships with nature.

Recall, that this article's call for humility rose from the HCH and that the HCH can only be analyzed by studying a place for a long time and in a way the transcends merely collecting quantified data (Hoy et al. 2024b). Compare that circumstance with Kimmerer (2002): "Traditional ecological knowledge [TEK] differs from scientific ecological knowledge [SEK] in a number of important ways. TEK observations tend to be qualitative, and they create a diachronic database, that is, a record of observations from a single locale over a long time period… In contrast, scientific observations… tend to be quantitative and often represent synchronic data or simultaneous observations from a wide range of sites, which frequently lack the long-term perspective of TEK."

The point of this comparison is that, on the uncommon occasions when SEK is manifest as a "record of observations from a single locale over a long time period" that are best understood as a qualitative narrative, SEK may well converge on an important facet of TEK. That is, the need for humans to be humble in our relationships with nonhuman persons (Trosper 1995), which, for many Indigenous cultures, includes ecosystems and biological communities (Quijada 2022). In SEK, the need for humility may rise most potently from seeing populations and ecosystems more as being uniquely storied than as being driven by machine-like rules. The basis for that association may be a view that machines are not persons (i.e., not deserving of moral consideration), but being uniquely storied is how we often speak about persons (who are deserving of moral consideration). The connection is enriched when one recognizes that the term *person* is rooted in a Greek word referring to a mask worn on stage. That is, a person is a character on the stage of life about which stories are told. If this convergence on humility is robust, then it would seem to represent an important instance of braiding Indigenous knowledge and Western science, which is called for by a growing number of leaders (e.g., Eisenberg et al. 2024).

The comparison with Kimmerer (2002) can also form the basis for a converse claim. That is, Western science's tendency to see nature as a machine aligns with its tendency to "represent [ecological phenomena with] synchronic data or simultaneous observations from a wide range of sites." That alignment likely arises because the general rules governing ecological phenomena that scientists are most interested to discover ought to be the same everywhere. This association between nature as a machine and synchronic data is likely a reason why Western science has tended to invest as little as it does in long-term ecological research (Vucetich et al. 2020).

Finally, we are not suggesting that humility is the only virtue to consider. Deciding what other virtues to embrace in public decision-making is beyond the scope of this essay. We focused on humility because old metaphysical views of science seem to have discouraged humility, but contemporary empirical understandings of ecological science—especially when viewed through the lens of the HCH—indicate its grave importance.

Acknowledging uncertainty

If the problem is uncertain forecasting, then one might think, why is it not sufficient to merely provide decision-makers with an assessment of that uncertainty? Why is it necessary to also infuse a decision with virtue or values, such as humility? One answer to those questions rises from appreciating that, according most formal decision theory, decisions depend importantly on probabilities that account for the uncertainty about the existence of various outcomes, given various actions, and utilities assigned to various outcomes. These utilities are expressions of the values and virtues on which a decision is made. This connection between utilities and values is featured in Hoy and colleagues (2024b), which analyzes decisions about whether to protect species from inbreeding depression when the evidence for inbreeding depression is uncertain. The lesson of that analysis is that, when there is significant uncertainty, the decision is strongly influenced by the utility assignments (i.e., values)—values that can be evaluated in terms of their humility. The importance of values when ecological assessments are uncertain can also be seen in the results of Heeren and colleagues (2017) and Karns and colleagues (2018). Finally, we note that utilities infused with humility would be an important route to infusing consequentialist thinking with humility.

A few qualifiers

The principles of virtue ethics have been developed variously; what we presented is a summary of MacIntrye's (1981) formulation. Also, we are far from the first to discuss virtue ethics in the context of conservation (e.g., Van Houtan 2006, Rapp and Nelson 2024). Furthermore, we used virtue ethics to discuss humility because it is a useful framework from which to discuss virtues, such as humility. But it is important to note that virtue ethics is not the only route to understanding humility. Finally, our description of consequentialism and deontology is not intended to imply that those frameworks cannot be infused with humility.

Conclusions

The interest is not to dismiss the views that nature is governed by rules of cause and effect, that science has an impressive capacity to forecast, or that the forecasted consequences of a decision should be disregarded. Rather, the concern is that the nature-as-machine worldview has been given too much weight—sometimes in ways that are easy to overlook because that view is so normalized. The nature-as-machine worldview needs a substantial counterweight. That counterweight can rise from also embracing a nature-as-history worldview. Recent ecological analysis gives scientific credibility to that view (Hoy et al. 2024a). This view also offers more reason for ecologists and users of ecological knowledge to analyze decisions about the environment in terms of humility and to favor humbler decisions.

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Author contributions

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