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Towards linking environmental law and science

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Abstract

Gaps between environmental science and environmental law may undermine sound environmental decision-making. We link perspectives and insights from science and law to highlight opportunities and challenges at the environmental science–law interface. The objectives of this paper are to assist scientists who wish to conduct and communicate science that informs environmental statutes, regulations, and associated operational policies (OPs), and to ensure the environmental lawyers (and others) working to ensure that these statutes, regulations, and OPs are appropriately informed by scientific evidence. We provide a conceptual model of how different kinds of science-based activities can feed into legislative and policy cycles, ranging from actionable science that can inform decision-making windows to retrospective analyses that can inform future regulations. We identify a series of major gaps and barriers that challenge the successful linking of environmental science and law. These include (1) the different time frames for science and law, (2) the different standards of proof for scientific and legal (un)certainty, (3) the need for effective scientific communication, (4) the multijurisdictional (federal, provincial, and Indigenous) nature of environmental law, and (5) the different ethical obligations of law and science. Addressing these challenges calls for bidirectional learning among scientists and lawyers and more intentional collaborations at the law–science interface.

Key words: conservation, co-production, cross-disciplinary, environmental assessment, environmental law, impact assessment, Indigenous law, policy windows, science communication, science policy

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Environmental law and science

Scientists are increasingly called upon to devote themselves to doing research for environmental sustainability (Lubchenco 1998, 2017; Baron 2016). Yet, environmental decision-making is governed by laws, regulations, and policies—the realm of policy-makers and lawyers. If we want these regulatory processes to be informed by scientific evidence, then it logically follows that there is a need to link law and science. For scientists interested in contributing to environmental sustainability through regulatory processes, it is not always clear how to do scientific activities that can be incorporated into these processes. Conversely, it is also not always clear to environmental lawyers how to appropriately gather, evaluate, and appropriately incorporate scientific evidence, principles, and limitations into statutory or regulatory provisions. These gaps can undermine sound environmental decision-making (Lubchenco 1998; Crowder et al. 2006; Cook et al. 2013; Sutherland et al. 2013; Baron 2016).

There are many different actors at the interface of law, policy, and science with diverse backgrounds who are linked in different ways throughout environmental law and policy processes. Although involved actors may range from elected officials to policy analysts to agency scientists within governments, our focus is on the perspective of external scientists and lawyers (i.e., those from non-governmental organizations (NGOs) or academia) trying to improve the scientific basis of environmental legislation and associated decision-making. Furthermore, our focus is primarily on applying science for the implementation or revision of legislation (i.e., environmental statutes, regulations, and closely associated operational policies (OPs)), rather than the more informal policy processes and science engagement that are often not outlined in law but that also guide natural resource management and conservation.

Approaching the issue with a diversity of backgrounds in environmental law, Indigenous law, and applied environmental science, we examine the linkages and disconnects between environmental science and environmental law and policy. Our primary objectives are to assist scientists who wish to conduct and communicate science that informs environmental statutes, regulations, and associated OPs, as well as the lawyers (and others) working to ensure that these statutes, regulations, and OPs are appropriately informed by scientific principles and evidence. Towards these objectives, we first identify different types of activities that scientists can undertake and which, if correctly designed, framed, and communicated, may influence environmental statutes, regulations, and policies. We then identify and discuss the barriers and opportunities for further improving knowledge transfer between environmental science and law. Although our focus is on Canadian environmental law, we believe that our insights likely apply to other jurisdictions. Fundamentally, addressing the barriers at the science–law interface requires collaboration and bidirectional learning among scientists and legal experts.

Science–law linkages throughout the policy cycle

Scientists and lawyers who seek to link science with environmental law can map out how different scientific activities inform the different phases of the cycles of policies, laws, and regulations. Environmental regulations can evolve through time, as conceptualized by a simplified policy cycle. A specific policy formulation will often be designed to inform decision-making, after which it is then implemented. Ideally, decisions and consequences are evaluated, and the results cycle back to redesign and improve the original formulation in what can be conceptualized as a simplified policy cycle (**Fig. 1**) (Howlett and Ramesh 1995). These shifts may be driven by natural legislative evolution or by political upheaval and political pressure (Phillis et al. 2013). For example, in the 1980s Fisheries and Oceans Canada (DFO) developed and released its 1986 Policy on the Management of Fish Habitat (Fisheries and Oceans Canada 1986) (design) to inform and guide its decision-making pursuant to section 35 of the federal *Fisheries Act* (decision-making) and on-the-ground practices to avoid, mitigate, and compensate for impacts on fish habitat (implementation). The policy was subsequently monitored for efficacy (evaluation) (Harper and Quigley 2005; Quigley and Harper 2006; Favaro and Olszynski 2017) but not formally by the DFO.

The same basic cycle can be modified to apply to legislation and subordinate regulation. For example, the Government of Canada has recently been reviewing the 2012 changes to the *Fisheries Act*

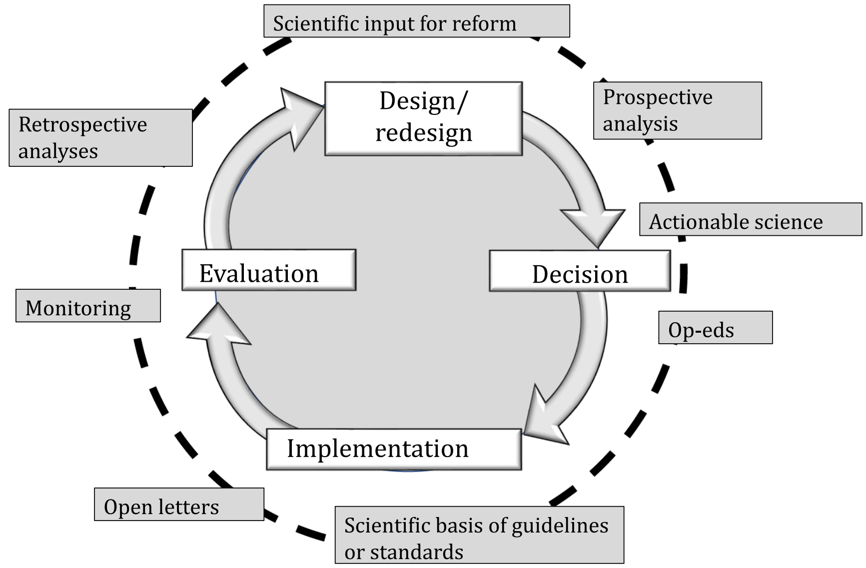

Fig. 1. Mapping out opportunities for law–science linkages across a simplified policy cycle. In this cycle, legislation, regulations, and closely associated operational policies generally have four phases, as illustrated in the white boxes. These different phases can be influenced by different science-based activities (grey boxes). In different circumstances these activities will map out differently across this cycle. Different activities may feed into multiple locations in the cycle (**Table 1**).

(redesign) to respond to widespread criticism by scientists and lawyers, among others, of those 2012 changes (evaluation) (Standing Committee on Fisheries and Oceans 2017).

Such cycles are simple conceptualizations—there can be important interacting scales of legislative cycles and nested sub-loops as well as more informal aspects of governance in natural resource management. The cycle can have its own internal scientific inputs (i.e., government scientists); our focus here is on those who are outside the policy cycle, such as in academia and NGOs.

Across these cycles, there are different science-based activities that can contribute to the evolution of environmental law and associated decision-making (**Fig. 1**, **Table 1**). These activities include ways of doing science as well as ways of communicating science. Some of these activities target discrete and transient decision-making windows, whereas others are more diffuse and contribute to elevating dialogue, creating political pressure, or generating the conditions to open new policy windows (Rose et al. 2017). This list is not exhaustive, nor do the activities occur in isolation. We do not discuss how scientists can also contribute more diffusely to environmental law through contributing to longer-term knowledge development (Owens et al. 2006).

Actionable science

We use the term "actionable science" to refer to tools, data, or analyses that can inform or guide decisions in the management of natural resources (Palmer 2012; Beier et al. 2017). We note that the term "actionable" in legal circles is used to describe something that can lead to legal action, such as slander leading to a lawsuit—this is not how we use the term.

Actionable science often targets a specific knowledge gap in a specific environmental decision-making context (i.e., policy window (Rose et al. 2017)). For example, during the environmental

Table 1. Examples of different activities for linking science to environmental law and decision-making across a simplified policy or regulatory cycle.

Activity	Potential targets in cycle	Examples
Actionable science	Decision-making, implementation	Science and Indigenous laws brought attention to the federal government's flawed herring management framework and strategies to rebuild declining herring stocks and resulted in an injunction to continue rebuilding fish stocks in Haida Gwaii (Council of the Haida Nation et al. v Minister of Fisheries and Oceans 2015).
Op-eds	Decision-making, evaluation, design, implementation	Brought attention to disregard for timelines for threatened species and suggested steps towards implementation of *Species at Risk Act* (Otto et al. 2013).
Open letters	Decision-making, evaluation, design, implementation	Identified scientific shortcomings of decision-making on major projects such as Enbridge Northern Gateway pipeline, Pacific NorthWest LNG, and Site C dam.
Monitoring	Evaluation	The actual rates of emissions of volatile organic compounds were found to be two to four times higher than those that were self-reported in oil sands facilities (Li et al. 2017).
Retrospective analyses	Evaluation	An empirical assessment of Fisheries and Oceans Canada's habitat management regime discovered that there was a net loss of habitat in contravention of the department's own policy (Favaro and Olszynski 2017).
Scientific input on policy reform	Evaluation, design	Environmental lawyers and scientists are collaborating on submissions to Parliamentary Committee studying the Oceans Act's Marine Protected Areas.
Scientific basis of guidelines/standards	Implementation	Scientists provided input for the standards for forestry sustainability certification (Tollefson et al. 2009).
Prospective policy analyses	Design	Air quality regulations were informed by scientific research showing reduced lake acidity following large reductions in sulphur emissions from Sudbury area smelters (Keller et al. 1998).

Note: These activities include different scientific approaches (e.g., monitoring) or different ways of communicating science (e.g., open letters) and were collectively identified as part of a symposium on linking environmental science and law.

assessment of a large energy industrial development in the Skeena River estuary (British Columbia, Canada), researchers discovered that the project was proposed for a location that was particularly important for young migratory salmon and that risks of the project were under-assessed (Carr-Harris et al. 2015; Moore et al. 2015, 2016). This science was submitted as evidence by First Nations' legal teams during environmental assessment comment periods and consultative processes and likely contributed to dialogue, negotiations, and project design modifications. Nevertheless, the Canadian Environmental Assessment Agency (CEAA) proceeded to grant the project approval, highlighting that while actionable science can play a role in environmental decision-making, the extent to which it will do so also depends on the relevant legislative and political context. As further discussed below, very few Canadian environment-related laws set out a scientific standard to guide government decision-making.

Actionable research may be best enabled through co-development of research programs with diverse communities and collaborators with close attention to emerging policy windows (Adams et al. 2014; Moon et al. 2014; Rose 2014; Beier et al. 2017; Keeler et al. 2017; Rose et al. 2017) rather than the classic approach of testing scientific theory that is often taught in university (Palmer et al. 2005; Keeler et al. 2017). Collaboration among scientists and lawyers, government agencies, Indigenous peoples, and stakeholders can enable the early identification of specific data gaps or uncertainties that will be relevant to environmental policy windows (Sutherland et al. 2012; Adams et al. 2014; Cook et al. 2014). For example, science and Haida laws brought attention to flaws in the federal government's management of herring. This resulted in an injunction to prevent re-opening the fishery to continue the process of rebuilding fish stocks in Haida Gwaii (Council of the Haida Nation et al. v Minister of Fisheries and Oceans 2015).

Scientific basis of guidelines or standards

Governments also rely on science to inform the formulation of standards and guidelines that are often incorporated in environmental laws and policies, such as fish stock assessment or air and water quality guidelines (Tollefson et al. 2009). In contrast to the actionable science described above, the timing windows for such processes are generally longer and consequently more in line with traditional research programs. As a recent example, Environment and Climate Change Canada announced its intention to draft regulations for coal mining effluent under the federal *Fisheries Act*, with a stakeholder consultation phase lasting well over a year (Environment and Climate Change Canada 2017).

Establishing the scientific foundation for guidelines or standards can be challenging for several reasons. "In a perfect world regulatory thresholds would correspond to clear ecological thresholds, but in practice, this is difficult to achieve because ecosystems are highly variable" (Hunter et al. 2009, p. 3). In fact, ecological thresholds may not actually exist for some processes or species (Huggett 2005; Reckhow 1994). Further, guidelines or standards are often set through an uneasy mixture of science and values. For example, the regulation of toxic substances is often based on "dose–response" relationships that must be translated to regulatory thresholds based on societal value judgments with respect to acceptable levels of risk. Although it may be challenging, scientists can help lawyers, legislators, and regulators to understand the limitations of science with respect to relevant ecological thresholds and objectives, while still emphasizing the strength of existing evidence (Tear et al. 2005; Hunter et al. 2009).

Op-eds

Commentary pieces written for widely read media outlets can identify issues with environmental law or decision-making and provide constructive solutions. These opinion editorials (op-eds) can communicate to a broad audience, generate further media attention, and bring lawmakers' and regulators' attention to an issue and the potential solution(s). For example, Otto et al. (2013) highlighted the lack of action for species at risk in Canada. Op-eds such as this can be published rapidly and be strategically aligned with key moments in the legislative cycle (**Fig. 1**).

Open letters

Scientists and law professors in Canada have used open letters signed by large groups of experts to show consensus from the scientific and environmental law community on evidence or law (where it exists). Similar to op-eds, these letters can target different portions of the policy and (or) legislative cycle; open letters have critiqued the scientific basis for the regulatory approval of particular projects such as the Site C dam (Schindler et al. 2015) and the Enbridge Northern Gateway pipeline (Chan et al. 2014), criticized pending amendments to core environmental laws such as the *Fisheries Act* (Schindler et al. 2012), and offered suggestions for environmental policy such as the *Canadian Environmental Assessment Act* (Jacob et al. 2016). These letters can garner substantial media attention and exert political pressure on decision-makers as well as enable future engagement.

Monitoring

Scientists can play key roles in quantifying the environmental consequences of management decisions. Although some monitoring may occur internally by industry proponents as part of regulatory compliance, this may be vulnerable to conflicts of interest (Casselman 2015) and government agencies with mandates to conduct monitoring may be limited by resources, capacity, or political pressure. Monitoring by independent scientists from academia or NGOs can provide independent validation of this regulatory monitoring and help fill knowledge gaps or oversights. For example, independent science has repeatedly found deficiencies in the environmental performance of oil sands developments (Kelly et al. 2010; Rooney et al. 2012). One study discovered that emissions of volatile organic compounds were two to four-and-a-half times higher and contained between nine and 53 more types of reportable compounds than self-reported measurements by oil sands facilities (Li et al. 2017). Although rapidly publishing the findings of monitoring is a key step, effective science communication can increase the impact of the research findings. For example, David Schindler brought several deformed whitefish to a press conference as a dramatic illustration of the risks of contamination from oil sands developments to aquatic ecosystems (Schindler 2010). Robust and independent science can evaluate the consequences of different policy and regulatory interventions. Impactful science communication can increase awareness of this science and the pressure for those insights to be acted upon.

Retrospective analyses

There are opportunities for lawyers and scientists to examine the effectiveness of environmental and resource management laws and policies. For example, two of the coauthors of this paper with law and science backgrounds collaborated on an empirical assessment of DFO's fish habitat management regime (Favaro and Olszynski 2017). They found that the regime was likely resulting in a net loss of habitat—a contravention of the department's "no net loss" policy, a central feature of the fish habitat legal regime in Canada. Other retrospective analyses have examined the (lack of a) regulatory burden of the *Fisheries Act* (Favaro et al. 2012), how economics overrides listing threatened species (Schultz et al. 2013), how the composition of recovery teams affects the identification of critical habitat for species at risk species (Taylor and Pinkus 2013), and the inadequacy of habitat mitigation efforts (Harper and Quigley 2005; Quigley and Harper 2006). Retrospective analyses can be a powerful way to reveal if there are systematic weaknesses in government decision-making, implementation, or policy and can be a driver for reform.

Scientific input for reform

Scientists and lawyers can collaborate to address potential empirical disconnects between science and environmental regulations, laws, and policies. The laws that govern decision-making may not effectively incorporate scientific understanding. For example, the Canadian federal *Oceans Act* authorizes the designation of areas of the sea for "special protection" as marine protected areas, yet that law does not reflect widespread findings in the scientific literature regarding which human activities are inconsistent with the purposes of these designated areas (Jamieson and Levings 2001; Hutchings et al. 2012; Vanderzwaag et al. 2012; Devillers et al. 2015; Bailey et al. 2016). Indigenous and environmental lawyers and scientists are currently collaborating on briefs and testimony to a Parliamentary Committee studying the *Oceans Act*'s Marine Protected Areas regime, making the case for amendments that would reflect scientific guidance on effective marine protected areas (Nowlan and Watson 2017). As another example, during the Parliamentary review of the federal *Fisheries Act*, environmental lawyers cited research on fish habitat impacts in the Skeena estuary from proposed energy development projects to bolster their arguments for the need for stronger habitat protection provisions in the law (Carr-Harris et al. 2015; Moore et al. 2016; Nowlan 2016). As these examples illustrate, legal researchers and practitioners can connect with scientists working in their area of interest for collaboration, and collectively they can communicate needs to improve and strengthen environmental law.

Prospective analyses

Before a law is revised, there are opportunities to quantify how legal changes might influence environmental protection if the law is passed. For example, the sulphur emission controls imposed in the

1980s that included a cap on sulphur dioxide (SO_2) and eventually led to the 1991 Canada–US Air Quality Agreement (Environment and Climate Change Canada 2013) were influenced by scientific research showing reduced lake acidity following large reductions in sulphur emissions from Sudbury area smelters (Keller et al. 1998). When a legal change is proposed, scientists and legal experts can provide prospective feedback. This feedback might not reach an open policy window, but it may contribute to policy when the window subsequently opens. For example, scientific studies on the likelihood of Atlantic cod stock recovery (Neubauer et al. 2013; Rose and Rowe 2015) may influence future decisions regarding re-opening the cod commercial fishery, which has been closed since the 1990s.

Engagement across the cycle

Multiple scientific activities across the legislative and policy cycle can build towards substantive impact in linking science and law (**Fig. 1**, **Table 1**). Initial engagement can foster future engagement and build towards policy impact. Initial efforts may also foster additional follow-up opportunities such as testifying as a witness in court or in a parliamentary hearing, providing written briefs based on research results to policy-makers, meeting with elected officials, or guiding public interest environmental law organizations, or as an informal advisor (Meyer et al. 2010).

Fostering law–science linkages

Our collective opinion and experience is that pro-active collaborations among environmental lawyers and scientists are relatively rare. This disconnect is surprising given that a "defining characteristic of environmental law and scholarship both historically and today is their link to science" (McEldowney and McEldowney 2011, p. 181). Environmental scientists and lawyers/legal scholars should seek out more formal ways to enable these linkages. One promising approach is to increase interdisciplinary environmental law–science collaborations. By focusing science on issues of direct regulatory concern and linking the results to the legal context, these collaborations can be more likely to inform regulatory reform (Findlay et al. 2009; Vanderzwaag et al. 2012; Owen and Noblet 2014). Lawyers and legal scholars can target communications to scientific audiences through their choice of journals. Organizers of environment-related conferences (e.g., ecology, hydrology, and conservation to name a few) can actively solicit participation from lawyers and NGOs with experience in this area. Similarly, organizers of environmental law conferences can invite scientists to participate. Learning should be bi-directional, as environmental lawyers have much to learn from scientists and scientists have much to learn from legal experts. Importantly, the science–law interface is a comfort zone for many NGOs and Indigenous governments, which can help foster law–science linkages. Indeed, diverse career pathways can be well suited to address the law–science gap that may be enabled by interdisciplinary training (Keeler et al. 2017; Zavaleta et al. 2017).

Environmental and Indigenous law practitioners and academics can work with scientists to guide research focus to increase the chances that studies and data will be relevant to different components of the legislative and policy cycle (**Fig. 1**). Through this collaborative process, scientists can direct their research programs so that they are more likely to be relevant to future environmental decision-making—something that should be explicitly encouraged by funding agencies. Collaborative horizon scanning among lawyers, Indigenous peoples, government policy and science experts, and external scientists may also be a productive exercise (Sutherland et al. 2012; Cook et al. 2014). Establishing these connections and collaborations can also help enable potential forthcoming collaborations and opportunities (i.e., need for an expert witness at a regulatory hearing) as well as help work towards overcoming major gaps and challenges for linking environmental law and science.

Addressing five challenges for linking law and science

Different time frames for science and law

Environmental decision-making by governments can happen more quickly than scientists may expect, and opportunities to participate often appear with little or no warning (Cook et al. 2014; Rose et al. 2017). If scientists want to contribute, they need to respond within legislated time limits. As one example, under the current *Canadian Environmental Assessment Act*, *2012*, members of the public (including the scientific community) only have 20 d to comment on whether an environmental assessment of a project should be conducted and may be asked to submit evidence for an assessment within relatively short time windows (e.g., 30 d). As another example, when project proponents apply for an authorization to destroy fish habitat pursuant to section 35 of the federal *Fisheries Act*, the applicable regulations require the relevant department (DFO) to issue authorizations within 90 d of the application being deemed complete. A further difficulty is that the government is not required to give public notice of these applications, and there is presently no public registry for such authorizations.

Such time windows are much shorter than those typical in the scientific process. Scientific research can take years or even decades, particularly for ecological studies conducted at large geographic scales. Data analyses can take weeks to months to years. The peer-review process may take months to years. Thus, it may be years from the time that a scientist seeks to answer a question to the time when they are "ready" to share results. By this time, it is likely that the window for contributing to a particular environmental decision point has closed (though the results can be shared with environmental lawyers to bolster future law reform efforts).

We offer scientists three suggestions for closing this time disconnect:

a. *Anticipate opportunities*. Scientists need to work to anticipate opportunities for scientific input across the adaptive management cycle, such as legislative reform or project evaluation (**Fig. 1**). As mentioned above, keeping up-to-date and horizon scanning, especially in collaboration with environmental law experts, NGOs, and government partners, can enable strategic foresight for scientists so they can be ready to hit policy windows when they open (Cook et al. 2014; Rose et al. 2017).

b. *Deliver on tight deadlines*. Given an opportunity for input into environmental decision-making, scientists may need to prioritize making that deadline above existing activities and obligations. These unexpected time commitments are challenging for scientists given demands on time for teaching, research, service, or advising. Research and academic institutions that meaningfully support and reward "science to serve society and the planet" (Keeler et al. 2017, p. 591) would further enable scientific involvement in these processes.

c. *Share science at different stages of the scientific process*. Ideally, actionable science will be peer reviewed, but this may not be possible in a short time frame. To address this problem, scientists can target journals that have rapid review and publication times, submit draft manuscripts, or use pre-print electronic journals to share results (such as bioRxiv.org), all the while working with environmental lawyers and other scientists to make sure that the state of understanding is made clear (see Standards of Proof section). Scientists also should appreciate that they have years or decades of training that provides them with real expertise to offer, even if it is only in the general field of interest. Lawyers advise that often a cursory review or synthesis by a scientist of existing data or information may be sufficient to inform policy or law, bearing in mind that "[s]cience delayed risks being justice denied" (Cranor 2006, p. 164).

Different standards of proof for scientific and legal (un)certainty

One of the key challenges in the interface between science and law is how to understand and clearly communicate certainty and uncertainty (Sutherland et al. 2013). Scientists need to learn how to express themselves in ways that are powerful and accessible as well as honest with regards to certainty. For instance, effective science communication with decision-makers entails leading with what is known rather than leading what is not known. This is counter to many scientists' inclinations and training.

The legal standard of proof varies according to both the type of law (criminal vs. tort vs. judicial review of government decisions vs. aboriginal law) and the arena of law (courts vs. legislatures vs. government agencies and departments), but it is fundamentally different than the threshold that generally underpins scientific hypothesis testing (e.g., $p < 0.05$). In negligence cases, for example, the legal standard of proof is a "balance of probabilities" or about 51%. In the criminal law context, the government must prove its case "beyond a reasonable doubt", which is widely understood as a higher standard (S.C.R. 2001). While there does not appear to be any uniform standard of proof in the regulatory context (e.g., in hearings before a CEAA panel or in decisions by DFO), when challenging such decisions the impugned analysis needs to be considered "unreasonable" for the decision to be set aside. This more qualitative standard could be considered higher than a balance of probabilities but further precision is difficult and can even be misleading. Canadian courts have also stated that it is not their role in this context to arbitrate conflicting scientific predictions, an approach criticized in the environmental law scholarship (Olszynski 2015). For the present, it appears that alleged errors or deficiencies that may appear minor to a court will not be sufficient to successfully challenge the decision or assessment that relies on (potentially flawed) science.

Scientists can solicit guidance from legal experts to become familiar with how different legal settings demand different levels of certainty. Scientists should also become familiar with the role of science and its certainty in Crown consultation and accommodation of Indigenous peoples' concerns in decisions or assessments.

To help translate scientific certainty to decision-makers, advisory bodies such as the Intergovernmental Panel on Climate Change have used scales that link Bayesian-based probabilities to legally equivalent phrases such as "beyond a reasonable doubt" or "reasonable grounds for belief" (Weiss 2003). Traditional frequentist statistics present the probability that a null hypothesis occurs due to chance, which is a somewhat convoluted output that will demand careful and clear explanation (e.g., "There is an X% change that this pattern occurred by chance alone."). The use of 95% confidence intervals of effect sizes will likely be more effective than using p-values alone (e.g., "We found that this chemical will increase cancer rates by X- to Y-fold."). Bayesian analytical approaches may provide scientists with estimates of probability (e.g., "There is X% chance that this is true given the data.") that are more easily communicated within law and policy realms (Ellison 1996). Further, emerging scientific approaches whose potential weaknesses have not yet been fully quantified by the scientific community may require careful assessment regarding the weight of evidence that these new technologies or analyses can provide. Regardless of their specific statistical approach, being comfortable with translating statistical outputs into understandable and compelling language that accurately captures scientific certainty and uncertainty is a key aspect of effectively linking science to law. Often the deciding factor for legal decision-makers (particularly judges) is the professional judgment of a credible scientific expert.

The need for effective scientific communication

The law–science interface demands effective scientific communication, as many have noted in papers and guidebooks (Owens et al. 2006; Baron 2010; Cornell et al. 2013; Smith et al. 2013; Cooke et al. 2017; Dunn and Laing 2017), though progress on improving scientific communication and engagement with nonscientists arguably remains mixed. With a few exceptions, the lawyers, judges, and elected officials who make and interpret environmental laws are not scientists and may not work to stay abreast of relevant scientific literature and concepts. Thus, the take-home messages from results and conclusions of scientific research need to be clear, strong, and free of jargon. Scientific communication may be strengthened if integrated with a personal story that resonates. While scientific training encourages scientists to focus on what is not known, communications training can emphasize on what is known, and where the weight of evidence lies. Furthermore, impactful scientific communication will frame results with the appropriate policy window or law (Owens et al. 2006; Rose 2014). This proper framing necessitates a nuanced understanding of how scientific evidence relates specifically to legal issues. Further, a fundamental question in science communication is identifying the research audience: who is the target of the communication, what do they already know, and what do they care about?

The multijurisdictional (federal, provincial, and Indigenous) nature of environmental law

Canadian environmental law is complex and involves multiple jurisdictional levels. It encompasses the common law (essentially judge-made law inherited from Britain and modified over time, e.g., negligence law) as well as legislation passed by federal, provincial, territorial, and municipal governments. Indigenous peoples have been governing their territories using their own laws since time immemorial. Indigenous laws are independent of the Canadian state and also govern and regulate land, water, and marine use (Borrows 2002; Clogg et al. 2016). Aboriginal law refers to the law of the Canadian state relating to Indigenous peoples, whereas Indigenous law refers to the legal traditions of Indigenous nations. International laws may also be involved.

If scientists engaged in actionable science or other law–science activities want to see their research applied to legal reforms (**Table 1**), it can be helpful to be aware of which level of government regulates the subject of their research and which legal processes are involved. Without knowledge and understanding of the multiple points of entry that may occur at different levels of government, the science may stay in the "ivory tower" (Baron 2010). While it is likely not feasible for scientists to become experts in all areas of law, talking to environmental law experts and NGOs about research can elevate their understanding of the legal context and opportunities for influence. In addition, if institutions want to empower the next generation of scientists to contribute to society, then they could offer classes in environmental policy and law (Keeler et al. 2017), including Indigenous laws (Finch 2012).

Indigenous laws often inform and parallel modern scientific and sustainability principles such as interconnectedness, balance, stewardship, respect, reciprocity, and responsibility. Many scholars have advocated for not only the reinvigoration and incorporation of Indigenous laws into decision-making and Canada's legal system (Borrows 2002, 2010; Christie 2007; Napoleon 2015) but also the reconciliation of Canada's legal system to pre-existing Indigenous laws and a deeper understanding of "the colonial enterprise and injustices it has so often created" (Finch 2012, p. 2.1.8). This reconciliation requires an understanding of Indigenous laws, which in turn requires a duty to learn on the part of all law practitioners (Finch 2012) and scientists. To do so will provide an opportunity to learn from Indigenous peoples' knowledge and laws governing millennia of successful land, water, and marine use and governance.

Different ethical obligations of law and science

Lawyers are bound by professional ethics to a number of parties—to the state, to courts and tribunals, to other lawyers, and to themselves. Foremost, however, lawyers are ethically bound to their clients to obtain the benefit of any and every remedy and defense that is authorized by law (National Judicial Institute 2013). In other words, they are advocates. Scientists, on the other hand, are supposed to assess evidence as objectively as possible. Thus, there may be an ethical disconnect between scientists and lawyers. Scientists risk their reputations and careers if they are perceived as lacking objectivity or being a "hired gun". Lawyers should recognize that scientists must meet their own expectations of scientific integrity in all evidence that they produce (Doremus 2008), and scientists should similarly be aware of lawyers' ethical obligations. Scientists and environmental lawyers should also be aware of moral and ethical obligations with respect to Indigenous peoples and Indigenous legal rights and title such as around the potential confidentiality of traditional knowledge.

Many environmental law concepts and principles, such as the precautionary principle or adaptive management, have both scientific and normative, or value-laden, aspects. In such instances it may be preferable for scientists to restrict themselves to the scientific aspects and allow lawyers (or others) to address the more value-laden aspects (e.g., what level of risk is society willing to tolerate?).

Scientists may be called to testify in environmental law disputes that end up in court. To be "court ready", lawyers advise scientists to keep organized and consistent paper trails and save relevant emails. Scientists should also keep in mind that written correspondence is often subject to disclosure rules (e.g., in the context of actual litigation) and access to information legislation and could be used in court. While these differences may seem challenging, it is important to note that they have successfully been addressed in other sectors, such as linkages between forensic sciences and law enforcement.

Conclusions

Addressing the disconnects between law and science poses real challenges and may require scientists and lawyers to leave their respective comfort zones. We are not suggesting that scientists start trying to rewrite environmental legislation or that lawyers should start directing field work and lab experiments. Laws should be written by experts in law, based on the considerations of empirical evidence and on other values (e.g., cultural, social, health, and economic). Indeed, our perspective and expertise is in the natural sciences sphere—social science has critical roles to play in environmental policy (Mascia et al. 2003). We also offer caution to scientists that want to wade into the environmental law arenas. The farther scientists stray from science and into decision-making and policy, the greater the risk of so-called "stealth advocacy" (Lackey 2007; Scott et al. 2007). If they decide to engage more directly with environmental law, scientists need to be aware of their own values and be clear to themselves and others about what role they are playing (e.g., advocate vs. honest broker). Scientists can play a powerful role as honest brokers of evidence following other best practices of applied science and science communication (Blockstein 2002; Smith et al. 2013; Rose 2014; Cooke et al. 2017). For those scientists that do actively engage in law and policy reform or are thinking of starting, this paper aims to provide guidance and clarification on how to positively make these connections. Similarly, there are opportunities for environmental law experts to collaborate more effectively with scientists to increase the scientific-basis of environmental decision-making.

With repeated calls for increases in collaborative and interdisciplinary science that tackles emerging conservation challenges (Meffe and Viederman 1995; Lubchenco 1998, 2017; Palmer 2012; Smith et al. 2013; Moon et al. 2014; Baron 2016; Palmer et al. 2016; Keeler et al. 2017), we suggest that the environmental science–law interface presents tangible and under-utilized opportunities for impact. There are, however, real challenges: institutional barriers, different standards of proof, and different ethical responsibilities to name a few. With global patterns emerging of deregulation of environmental legislation (Chapron et al. 2017), there is a need and opportunity for scientists and lawyers to look towards each other for insights and collaborations. Linking science to law should improve outcomes of decision-making for the benefit humanity and the environment.

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Author contributions

JWM, LN, MO, ALJ, BF, LC, GLT-LW-D, and JW conceived and designed the study. JWM and LN contributed resources. JWM, LN, MO, ALJ, BF, LC, GLT-LW-D, and JW drafted or revised the manuscript.

Competing interests

BF is currently serving as a Subject Editor for FACETS, but was not involved in review or editorial decisions regarding this manuscript.

Data accessibility statement

All relevant data are within the paper.

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