



REVIEW SUMMARY

CONSERVATION AND LAW

Science and the legal rights of nature

Yaffa Epstein*, Aaron M. Ellison, Hugo Echeverría, Jessica K. Abbott

BACKGROUND: Over the past 15 years, legal rights for nature have gone from a fanciful idea to legal fact in a growing number of countries. To date, these laws have had the greatest legal impact in the Global South, where Indigenous activism, political conflicts, and lack of effective environmental laws have provided opportunity and incentive for legal experimentation, but they have also been enacted at the local level in North America. In late 2022, Spain enacted the first rights-of-nature law in Europe, establishing the legal personhood of the Mar Menor lagoon.

Rights-of-nature laws have reached a critical point at which they may either be normalized or marginalized. They have captured the public imagination, leading to growing advocacy for, and enactment of, these laws. Some of these laws have succeeded in protecting the environment, often with the aid of engagement from scientists who have helped to interpret and implement them. Others have failed, often not because of the concept that nature can have rights but due to lack of clarity—scientific or otherwise—about how the law should be applied. The engagement of scientists with these laws as they are enacted, implemented, and enforced has been a key factor in judges' ability to apply them.

ADVANCES: Rights-of-nature laws have been enacted in Ecuador, Bolivia, New Zealand, Uganda, Panama, Spain, and US and Canadian localities, among others. Courts in other jurisdictions including Colombia, Bangladesh, and

India have also recognized rights of nature based on legal principles within those jurisdictions. These laws and court decisions necessarily reference scientific concepts in defining new right-holding entities and new rights for these entities. While some of these laws are so new that they have yet to be applied by courts, there have been dozens of court decisions in the past 5 years interpreting rights of nature laws. Ecuador is a prominent example: Judicial application of nature's constitutional rights has resulted in court decisions delineating rights for species, ecosystems, waterways, and even individual animals. Scientific concepts pertaining to rights of nature laws analyzed by courts include life cycles, evolutionary processes, ecological flows, and species, among many others. The level of judicial engagement with natural science in making these analyses has varied. While the Ecuador Constitutional Court has actively worked to involve natural scientists in its legal decision-making about the rights of natural entities, US courts have thus far declined to engage with scientific aspects of rights-of-nature laws, holding in one case that a natural entity's rights to "exist, flourish, and naturally evolve" were unconstitutionally vague. Spain's Mar Menor legal personhood law is being challenged in the Spanish Constitutional Court on similar grounds.

OUTLOOK: When courts have difficulty interpreting scientific concepts used in law, the law's ability to reach legislative goals is hindered. We identify areas where future research is needed.

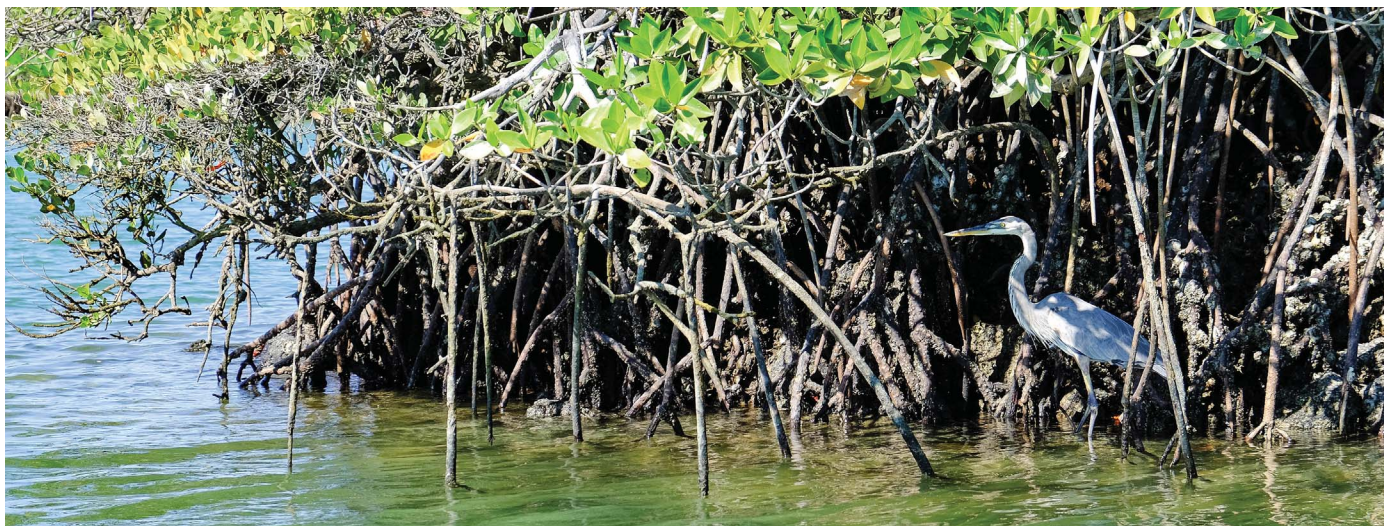
Because legal decision-makers alone may not have the expertise to understand what natural legal rights entail, interdisciplinary research is urgently needed if these laws are to be meaningful. Legal and natural scientists should examine legal-scientific concepts such as the right to evolutionary processes in particular legal contexts, to clarify what type of scientific input is needed to protect this right for different types of natural entities. By contributing to interdisciplinary analyses of rights-of-nature laws before disputes arise, scientists can help contribute to the effectiveness of these laws. The availability of credible scholarly analysis of legal-scientific terms used in law would make these rights more tangible and accessible to the judges whose role it is to apply them. Although scientific uncertainty often cannot be eliminated, its reduction in turn reduces legal uncertainty and thus helps meet the objection that rights-of-nature laws are too vague to be applied. Another type of interdisciplinary scholarship that would assist the functioning of rights-of-nature laws would be the examination of the duties of nature. Although some rights-of-nature laws grant rights for nature without corresponding duties, others equate nature to a legal person with both rights and duties. Uncertainty over liabilities and duties of nature has been an impediment to implementing some rights-of-nature laws. Scientists can help legal systems comprehend nature's potential legal obligations (e.g., "ecosystem services"), and what environmental protection measures may also be legally required to ensure natural entities can continue to fulfill these obligations. ■

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Mangroves in Ecuador, such as these at Black Turtle Cove on Santa Cruz, Galapagos, have legal rights that have been recognized in court.

REVIEW

CONSERVATION AND LAW

Science and the legal rights of nature

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We review the use of science by lawmakers and courts in implementing or rejecting legal rights for nature in Ecuador, India, the United States, and other jurisdictions where some type of rights of nature have been recognized in the legal system. We then use the “right to evolve” to exemplify how interdisciplinary work can (i) help courts effectively define what this right might entail; (ii) inform how it might be applied in different circumstances; and (iii) provide a template for how scientists and legal scholars can generate the interdisciplinary scholarship necessary to understand and implement the growing body of rights-of-nature laws, and environmental law more generally. We conclude by pointing to what further research is needed to understand and effectively implement the growing body of rights-of-nature laws.

Despite an ever-growing body of environmental laws, biodiversity loss and other catastrophic environmental damage continue to occur worldwide (1). Strengthening environmental laws and improving their enforcement is considered one of the keys to reversing this trend (1). Rights-of-nature laws are one instrument used in an increasing number of countries with a goal of improving legal systems’ ability to protect the environment (1). These laws, which establish legal rights for nature or elements of it (e.g., species, ecosystems), have reached a critical point at which they may be either normalized or marginalized. They have engaged the public imagination, leading to growing advocacy for, and enactment of, these laws (Table 1) (2). Some of these laws have been used successfully to protect the environment, often with the aid of expertise from scientists who have helped interpret and implement them. Others have failed, often not because of the failure of the concept that nature can have rights but rather because of lack of clarity—scientific or otherwise—about how the law should be applied. For these laws to work as intended in the legal systems in which they reside, it is necessary for life and earth scientists, along with social and political scientists and others, to engage with these laws as they are enacted, implemented, and enforced (Fig. 1). Without scientific input at the various stages of environmental law making, such laws are more likely to fail to be effective, and if they fail too often rights-of-nature laws may cease to be enacted as politicians and civil society will think they are unworkable. With engage-

ment from scientists however, as recent court decisions in Ecuador demonstrate, rights-of-nature laws are more likely to be upheld by courts and effectively implemented, which could in turn lead to the continued growth in influence and importance of these laws in protecting the natural world.

As scholars have examined in a variety of contexts, scientific information is often necessary to give effect to laws (3, 4, 5, 6). This is true in all areas of law, such as tort law, in which scientific expertise is often needed to determine risk or causation (7), but it is especially true in environmental law (3). Scientific concepts which courts have had to interpret in

recent years include, for example, genetically modified organism (8), point-source pollution (9), and climate change (10). These terms describe or use scientific ideas but when they are used in the law they also become legal terms (4). Differing interpretations of these terms and concepts in different disciplines not only affect specific decisions but also make it difficult for various parties to agree whether a given action complies with the law. How judges or other decision-makers understand, misunderstand, or ignore scientific concepts affects the outcomes of cases and the ability of the law to achieve its legislative goals (11).

The need to grapple with science and scientific uncertainty is a persistent conundrum in environmental law, and rights-of-nature laws present additional challenges. First, they use science in new contexts; it may be impossible to understand who the new rights holders are or what rights they have at all without contributions from scientists (12). Second, because these types of law seem unfamiliar to judges and decision-makers, they may be hesitant as to how and when to use science to apply them, even when the laws use similar terms or protect similar entities or processes as other environmental laws. The risks of decision-makers failing to properly apply scientific aspects of the new laws are therefore higher, as is the corresponding risk that the laws will be ineffective.

Clarification is needed regarding our use of “science,” a term which itself does not have a universally agreed-upon definition (13). By



Fig. 1. Stages in the life cycle of a law where scientists' input can help rights-of-nature laws work.

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science, we mean the organization of knowledge obtained through observations and experiments that leads to testable and refutable predictions about the causes of observable phenomena, and information that is produced by experts within disciplines that utilize these processes (4). Although this type of science is often referred to as “Western science”, its origins in, for example, China, India, Egypt, and Mesopotamia transcend hemispheres and contemporary geographic boundaries (14). We acknowledge that other systems of knowledge, such as Indigenous Traditional Ecological Knowledge (ITEK) have and continue to make important contributions to the creation and interpretation of rights-of-nature laws, especially where rights of nature intersect with the rights and sovereignty of Indigenous Peoples (15, 16, 17, 18, 19, 20). “Western science” (hereafter referred to as “science”) is frequently and necessarily applied to current legal formulations and applications of all types of rights-of-nature laws, however, particularly those that explicitly specify scientific terms and processes or create, for example, scientific advisory boards. There has been very little scholarly consideration of how science is used in formulating and applying rights-of-nature laws; we delimit our Review to addressing this gap in the literature.

Here, we review central scientific aspects of rights-of-nature laws and litigation. In the next section, we review some of the scientific concepts embedded within the laws themselves.

We then examine the use of science in court decisions that have interpreted rights-of-nature laws. Finally, we use the example of the “right to evolve” to discuss some difficulties in applying scientific concepts in rights-of-nature laws and identify some possible solutions to these difficulties. We conclude with a call for further interdisciplinary collaborations between legal scholars and scientists to help courts and others understand legal “rights of nature” and their relationship with other environmental laws, so that all such laws can have their intended impact of protecting the environment.

Scientific concepts in rights-of-nature laws

Over the past 15 years, legal rights for nature have gone from a fanciful idea to a legal fact in at least 20 countries (2, 21). To date, these laws have had the greatest legal impact in the Global South, where Indigenous activism, political conflicts, and lack of effective environmental laws provided opportunity and incentive for legal experimentation, but they have also attracted considerable attention in North America and Europe (19). Rights-of-nature laws take a variety of forms and grant rights to different types of rights holders, from the metaphysical “Mother Earth” to certain types of natural features such as rivers or ecosystems, to specifically delineated ecosystems (22). The types of rights recognized or afforded to natural entities also vary (18). Some laws assign natural entities legal personhood—a

legal concept that accords entities the ability to have their rights and duties enforced by courts—similar to a corporation. Other laws enumerate substantive rights for natural entities, including property rights, the right to life, diversity of life, clean air, evolutionary capacity, protection, or restoration. Some of these rights, such as the right to property and life, resemble human rights whereas others such as the right to evolutionary capacity are unique to nonhuman natural entities (although humans also evolve, as of yet there is no recognized human right to evolve). In this section, we identify scientific concepts inherent in these rights-of-nature laws in a non-exhaustive set of examples and discuss the potential role and limitations of scientific input in implementing natures’ rights.

Ecuador

Article 71 of Ecuador’s constitution sets out rights of nature, or Pachamama, to “integral respect for its existence and for the maintenance and regeneration of its life cycles, structure, functions, and evolutionary processes,” and the right to be restored. Further, the state has an obligation to take measures to prevent the “extinction of species, the destruction of ecosystems, and the permanent alteration of natural cycles” (23).

Pachamama is an Andean goddess associated with fertility and harvest and is used in the law to represent nature as a living whole

Table 1. Examples of rights-of-nature laws.

Ecuador Constitution Art. 71 (2008)	“Nature, or Pachamama, where life is reproduced and occurs, has the right to integral respect for its existence and for the maintenance and regeneration of its life cycles, structure, functions and evolutionary processes.”
Bolivia Law 071 on the Rights of Mother Earth (2010)	Mother Earth has the right to life, which includes the “right to maintain the integrity of living systems and natural processes that sustain them, and capacities and conditions for regeneration,” as well as rights to diversity of life, equilibrium, and restoration, among others.
Rights of Manoomin (Wild Rice), White Earth Band of Ojibwe (2018)	“Manoomin, or wild rice, within the White Earth Reservation possesses inherent rights to exist, flourish, regenerate, and evolve, as well as inherent rights to restoration, recovery, and preservation.”
Uganda National Environment Act Art. 4 (2019)	“Nature has the right to exist, persist, maintain and regenerate its vital cycles, structure, functions and its processes in evolution.”
Lake Erie Bill of Rights, Toledo, OH, USA (2019) (overturned by court decision)	Lake Erie has the “right to exist, flourish, and naturally evolve.”
Recognition of the legal personality and rights of the Magpie River-Muteshekau-shipu Res. 025-21, Minganie Regional County Municipality, Quebec, Canada (2021)	The Magpie River has the fundamental rights, among others “to evolve naturally, to be preserved and to be protected”
Panama Law 287 recognizing the rights of nature and obligations of the state related to these rights (2022)	Nature has the right to exist, persist, and regenerate its life cycles; to timely and effective restoration; and to the preservation of its water cycles.
Rights of Mar Menor, Spain (2022)	The Mar Menor lagoon and its basin are recognized as having the rights to protection, conservation, maintenance and, if necessary, restoration, as well as the rights to exist as an ecosystem and to evolve naturally.

although, as argued by scholars, this legal Pachamama does not clearly correspond to Indigenous philosophies (19). The constitution's preamble also equates Pachamama with "Mother Earth" and states that we are a part of nature or Pachamama—i.e., humans are also part of this rights-bearing entity. Although it is unclear from the text how exactly this entity should be defined, it apparently contains elements that cannot be given content by or defined explicitly by scientists alone. For example, nature has the right to "respect for its existence." "Respect" may be defined sociologically whereas the meaning of "existence" can be debated by philosophers, scientists, and others. Other rights appear more amenable to scientific input or understanding including rights to life cycles, ecological functions, evolutionary processes, restoration, and prevention of species' extinctions.

New Zealand

In contrast to Ecuador, New Zealand does not recognize the rights of nature as a collective whole. Rather, New Zealand recognizes the rights of specific natural entities that are significant to particular Iwi (tribes). These entities are defined in both geographical and metaphysical terms (24) and have been granted legal personhood and property rights (18). The rights-bearing entity Te Awa Tupua, for example, is defined in a 2017 law as "an indivisible and living whole, comprising the Whanganui River from the mountains to the sea, incorporating all its physical and metaphysical elements" (25). As with Pachamama, science is needed to understand the physical and biological aspects of this new legal person but cannot solely define it.

Compared with many other rights-of-nature laws that have nature protection as a central goal, these acts are primarily aimed at protecting the rights of Indigenous Peoples and incorporating their conceptions of natural entities into the national legal system (26). For example, in vesting property rights in the Whanganui riverbed, the New Zealand government acknowledged that it did not own the natural entity itself. It further ceded decision-making authority to a body appointed to act in the interests of the river, comprised of representatives of the Indigenous Whanganui Iwi and the New Zealand government. ITEK may be of greater importance relative to Western science in applying the New Zealand rights-of-nature laws than some others, although defining the boundaries of the recognized legal persons may require reference to information derived from both ITEK and scientific epistemology (17) (27).

Panama

Panama's 2022 law on rights of nature sets out both nature's rights and the obligations of

the state to protect them (28). The law defines "nature" as a "collective entity, indivisible and self-regulated, shaped by its elements, biodiversity, and interrelated ecosystems." No metaphysical concepts are referred to, but both scientific input and other expertise, such as ITEK, may contribute to defining this rights holder. Nature's rights are referred to as "fundamental" and thus comparable to human rights.

The law sets out a rather comprehensive set of rights, many of which contain scientific concepts. Some of these rights adhere to nature as a collective whole, whereas others "extend to all living beings, elements, and ecosystems of which [nature] is composed." Similar to several earlier rights-of-nature laws, these rights include "the right to exist, persist, and regenerate their vital cycles," the right to be restored, the right to air quality, the right to maintain its biodiversity, and "the right to regenerate its vital cycles ... in such a way that it will not lead to an imbalance of the development and integral maintenance of its natural cycles nor evolution of ecosystems." Although scientific information is clearly needed to understand these rights, their formulation is problematic from an ecological perspective in that there is no guarantee that natural evolution would always act to maintain ecological balance. But given that the law requires this balance scientists may be called upon to illuminate how to maintain it.

Spain

In 2022, Spain enacted the first rights-of-nature law in Europe (29). This law recognizes the legal personality of the Mar Menor lagoon and its basin, including the "entire lagoon marine ecosystem," whose size, location, and specific aquifers are defined with geographical precision and in scientifically recognizable terms (30). The preamble to the law cites both ecological and humanitarian reasons for assigning legal rights to the lagoon, but, unlike the laws in Ecuador, New Zealand, and others, the definition is stated without reference to metaphysical concepts.

The rights accorded to Mar Menor include both legal personhood and substantive rights. The latter include the rights to protection, conservation, maintenance, and restoration, and the rights to exist as an ecosystem and to evolve naturally. What these rights entail are further legally defined. For example, the "right to exist and naturally evolve" is further clarified: "The Mar Menor is governed by a natural order or ecological law that makes it possible for it to exist as a lagoon ecosystem and as a terrestrial ecosystem in its basin. The right to exist means respecting this ecological law, to ensure the balance and regulation capacity of the ecosystem in the face of the imbalance caused by anthropic pressures coming mainly from the watershed." Although this gives some

indication how the right to exist and evolve are to be applied, it also invites further scientific input in applying "ecological law," though what is meant by this term can likely not be defined by scientists alone. The Mar Menor law establishes several bodies to help protect the rights of Mar Menor, including scientific, representative, and monitoring committees. The scientific committee is tasked with advising the other committees, particularly about the ecological status of and threats to the ecosystem, as well as appropriate conservation measures. This law thus explicitly creates a pathway for scientific knowledge to interact with political and other expertise in protecting nature's rights.

USA

There are currently no state or national laws in the USA giving rights to nature, but dozens of rights-of-nature laws have been adopted at local and tribal levels. Below are two examples.

Santa Monica

Santa Monica's 2013 Sustainability Rights Ordinance recognizes the rights of "natural communities and ecosystems" to "exist and flourish" (31). The terms used to describe types of rights holders—natural communities and ecosystems—are used broadly by ecologists and defined further in the law as "groundwater aquifers, atmospheric systems, marine waters, and native species within the boundaries of the City." Ecologists, hydrologists, and geologists might help identify which natural communities and ecosystems meet the legal definition required by this ordinance.

White Earth nation

Several indigenous nations have enacted laws or resolutions pertaining to rights of nature. In 2018, for example, the White Earth Band of Ojibwe, located in Minnesota, recognized the rights of Manoomin, or wild rice, to exist, flourish, regenerate, and evolve, and its rights to restoration, recovery, and preservation (32). Ecologists and botanists could help identify, for example, the conditions necessary for wild rice to evolve.

A few local rights-of-nature laws have been overturned by courts for violating state laws or the US Constitution. However, the reason for most of these negative rulings was that many of these laws, which were drafted with the aid of a nongovernmental organization, were intended as "civil disobedience" (33). They frequently purported to supersede state law and strip corporations of legal personhood (33) and thus were in conflict with the US or state legal systems. Santa Monica's 2013 ordinance, however, avoided these conflicts and continues to build its environmental laws and policies based on these rights (34).

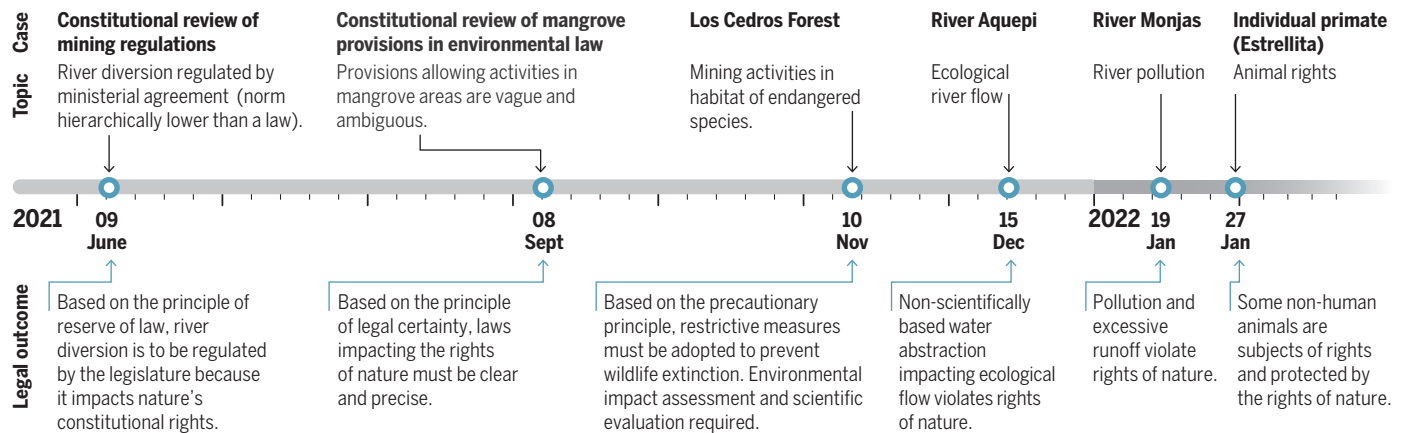


Fig. 2. Rights of Nature Cases in the Constitutional Court of Ecuador, 2021–2022.

Use of science in adjudicating the rights of nature

In this section, we discuss how scientific questions accompanying the implementation or enforcement of rights of nature have been dealt with by courts. Although rights for natural entities often include religious, spiritual, and social elements that may make it impossible to reduce them “to a host of ecological criteria” (35), it is necessary to also consider scientific criteria to interpret rights of nature. Even for rights that are analogous to recognized human rights such as the right to life, science may be needed to clarify similarly formulated rights of nature.

It is important to examine not only laws themselves but also how they are interpreted by courts. That is because laws alone, no matter how carefully drafted, cannot protect the environment unless they are also applied and enforced. It is often unclear what the impact of a law will be until it is tested in court. Although many rights of nature laws have not yet been litigated there have been dozens of relevant court decisions in the past 5 years, particularly in Ecuador, Bolivia, and Colombia. We review the use of science in several important examples of these decisions.

A judicial push to utilize scientific knowledge in Ecuador

As noted above, Ecuador was among the first countries to legally recognize rights for nature. For more than a decade after this recognition however, few cases on rights of nature were decided by courts, and it was unclear to what extent these constitutional provisions would affect the legal system or the environment (2). However, in 2019, a new Constitutional Court took office. In 2021 and 2022, Ecuador's Constitutional Court made six important decisions on how rights of nature should be applied (Fig. 2). The constitution protects the rights of nature as a whole to its life cycles, structure, functions

and evolutionary processes but in many of these cases the Constitutional Court also recognized the rights of specific natural entities in order to identify the harms suffered as well as potential remedies (36). Scientific considerations and testimony have been essential to understanding and protecting the rights of nature and its interdependent elements.

Mining regulations case

One of the first rights-of-nature cases decided by the Constitutional Court was the June 2021 Mining Regulations case (37). This case considered whether administrative regulations for modifying or diverting watercourses to support mining activities violated the rights of nature by risking permanent damage to the seasonal rhythms and hydrologic regimes of the rivers, which could cause changes to the chemical composition of the water or other changes that could affect species and ecosystems (paragraphs 11 and 12). It was also alleged that such diversions would risk the ecological flows of the river, which were also protected under the 2008 Constitution.

In its decision, the court extensively analyzed natural science texts to understand ecological flows and adopted the following definition: “the quantity, quality, and timing of water flow needed to sustain ecosystems and the services they provide to humans” (paragraphs 56 to 61). Because diverting watercourses could affect ecological flows and thus constitutional rights, decisions to do so could not be made through simple administrative procedures, the court ruled, but rather through a decision-making process that took full account of the constitutional rights of nature. The court further required that future authorizations to divert watercourses must be based on independent technical studies that could ensure that the proposed diversion would not lead to the extinction of species, the destruction of ecosystems, or the permanent alteration of

natural cycles (paragraph 80). This decision made clear that hydrological expertise would be needed to determine when modifications to a watercourse violate the rights of nature and other constitutional rights.

Los Cedros case

Los Cedros is a cloud forest of 6400 hectares. The bioregion of the Andes and the bioregion of Choco converge in Los Cedros, making it a high biodiversity area. It is the habitat of endangered flora and fauna including the critically endangered jaguar and spider monkey. In 2017, the State of Ecuador authorized exploration for industrial mining within the forest. This was challenged by the head of the local municipality. Although Los Cedros is designated as protected forest, mining was allowed in this type of designated area. The Constitutional Court's decision in the November 2021 Los Cedros case (38) extensively developed binding rights-of-nature jurisprudence and indicated to lower courts how future rights-of-nature cases should be analyzed and decided. The court expressed “much concern” that the rights of nature had not yet been given sufficient consideration in the legal system (paragraph 34). It saw its task in this case as deciding not whether certain mining permits were illegal in light of conservation law (on which the lower courts had focused), but rather whether the mining permits violated nature's rights to have its existence fully respected, or its right to maintain and regenerate its cycles, structure, functions, and evolutionary processes (paragraph 25). In adjudicating nature's rights, the court considered that it also needed to “analyze the rights of existence held by the animal and plant species of Los Cedros, as well as the right of this ecosystem to maintain its cycles, structure, functions and evolutionary process” (paragraph 26). In other words, the court considered that not only “nature” as a whole or

Pachamama had constitutional rights but that these rights extended to animal and plant species and the Los Cedros ecosystem.

This case made clear the importance of scientific evidence to adjudicating rights of nature. The court not only heard testimony from dozens of scientists and scholars but also “requested that national or international academic institutions that had performed scientific research on the Los Cedros Protected Forest...submit any information they considered relevant for the resolution of the [case]” (paragraph 4). The court began its analysis by carefully describing the Los Cedros ecosystem in “ecological terms” (paragraph 12). It then noted that “the characteristics of this ecosystem and the species that comprise it will be discussed further based on verified scientific information,” and that this information would be considered “alongside the rights alleged to have been violated” (paragraph 13).

The court also noted that the constitutional rights of nature are “an intellectual convergence of the knowledge of indigenous peoples and modern Western science...and [in also referring to Mother Earth] recalls the essential relationship between human beings and nature” (paragraph 29). The court thus saw no contradiction in applying Western science to interpreting Pachamama’s rights.

In one example of the court’s incorporation of scientific concepts into legal analysis, the court considered that nature’s right to “regeneration of its vital cycles, structure, functions and evolutionary processes” required understanding “the ecological tolerance principle, which holds that natural systems can only function adaptively within an environment whose basic characteristics have not been altered beyond what is optimal for that system...For each particular characteristic of the environment (amount of rain, humidity, solar radiation, etc.) there are limits beyond which organisms can no longer grow, reproduce, and ultimately survive. Thus, when the ecological tolerance level is exceeded it is impossible to exercise the right to reproduce life cycles” (paragraph 44). The court extensively referred to scientific sources to help it understand the scientific concepts necessary to interpret nature’s constitutional rights.

On the necessity to protect species, the court applied the biological species concept (39) in its statement that “[t]he biotic component of the ecosystem is the species that constitute it. A species is defined as the set of organisms capable of interbreeding and producing fertile offspring...Often, over geological time, individuals that separate from the original population and become isolated from the rest may reach a sufficient degree of differentiation to become a new species” (paragraph 46). The court then argued that nature’s right to existence meant protecting it from human

activities that would lead to species extinction, which the court considered equivalent to genocide (paragraph 68).

Importantly, the court held that the precautionary principle, a principle which generally applies to threats to human health or the environment and which has been widely recognized in international agreements such as the 1992 Rio Declaration on the Environment and Human Development, must be applied when there is a potential risk of serious and irreversible damage to the rights of nature. This means, according to the court, that potentially damaging activities cannot be carried out unless there is scientific certainty that the rights of nature will not be irreparably harmed (paragraph 62). Therefore, scientific input will always be needed in determining whether human activities violate the rights of nature.

The integration of scientific, social, and spiritual data in India

No country-wide rights-of-nature laws have been enacted in India, but the highest courts in several states have recognized the rights of nature in court decisions. Similar to courts in several jurisdictions in other countries including Colombia and Bangladesh, these Indian courts considered that principles of law within their legal systems enabled or required them to recognize new legal persons.

Uttarakhand High Court

In its 2017 ruling, *Mohd Salim v. State of Uttarakhand* and others. The High Court of Uttarakhand at Nainital declared the Ganges and Yamuna Rivers and “all their tributaries, streams, every natural water flowing with flow continuously or intermittently of these rivers” to have “the status of a legal person with all corresponding rights, duties and liabilities of a living person in order to preserve and conserve” the rivers. Although the entities recognized were geographical features—waterways—the court, in its decision, emphasized the spiritual aspects of the two rivers: they are “sacred and revered” by Hindus. The state of Uttarakhand and a Ganges conservation organization were declared “in loco parentis” for the rivers, “as the human face to protect, conserve and preserve” the rivers and their tributaries. The court followed up ten days later with an additional decision, *Lalit Miglani v. State of Uttarakhand* and others, granting the same type of rights to the glaciers that feed the two rivers (40). This wide-ranging decision contained extensive literary descriptions of spiritual and cultural dimensions of nature in India. It also contained extensive quotations from scientific papers describing Himalayan ecosystems and biodiversity (pages 11 to 17).

The decision discussed the interdependence of natural entities in quasicological terms.

For example, “Trees are the buffer zone necessary to protect the glaciers from direct and indirect heat. One tree sustains life of thousand of insects. Birds chirp and make their nests on the trees. Trees are mini-reservoirs and have a capacity to store the water. The water stored by the trees is released slowly. The Oak tree preserves about 75,000 gallons of pure water. Plucking of one leaf, grass blade also damages the environment universally.” The court also used complementary spiritual and scientific justifications for the rights granted: “Rivers and Lakes have intrinsic rights not to be polluted. Polluting and damaging the rivers, forests, lakes, water bodies, air and glaciers will be legally equivalent to harming, hurting and causing injury to person. Rivers, Forests, Lakes, Water Bodies, Air, Glaciers and Springs have a right to exist, persist, maintain, sustain and regenerate their own vital ecology system. The rivers are not just water bodies. These are scientifically and biologically living...Rivers are grasping for breath. We must recognize and bestow the Constitutional legal rights to the Mother Earth”.

Further, because of the ecological interdependence of different natural entities, the court deemed it necessary to grant personhood to a wide variety of entities, declaring “Glaciers including Gangotri & Yamunotri, rivers, streams, rivulets, lakes, air, meadows, dales, jungles, forests wetlands, grasslands, springs and waterfalls, legal entity/legal person/juristic person/judicial person/moral person/artificial person having the status of a legal person, with all corresponding rights, duties and liabilities of a living person, in order to preserve and conserve them. They are also accorded the rights akin to fundamental rights/legal rights.” The Indian Supreme Court later stayed the Ganges and Yamuna decision, not because it disagreed with the ability of the court to create these legal persons, but because of concerns over the potential liability of the state if these entities should be sued—that is, how nature’s duties would be interpreted (40). Although this decision was stayed, the reasoning has not been overturned and has been influential in some other cases.

Judicial refusal to engage with science in the USA Drewes Farms Partnership v. Toledo

The rights of Lake Erie and the Lake Erie Watershed to “exist, flourish, and naturally evolve” were enacted through a ballot initiative in Toledo, Ohio. This law was challenged in court by a farm company and the state of Ohio. In *Drewes Farms Partnership versus Toledo*, the court refused to contemplate what the new rights meant at all in its decision to invalidate the Lake Erie Bill of Rights.

This law was one of many local laws in the USA that purported to invalidate permits granted by state or other authorities that

would violate nature's rights and to invalidate the legal personhood of corporations that would violate nature's rights. These provisions conflict with US jurisprudence on federalism and corporate rights, and the court unsurprisingly struck down the law. However, the court decided the case on other grounds, ruling that the rights to "exist, flourish, and naturally evolve" were unconstitutionally vague. In its order invalidating the law, the court asked "[w]hat conduct infringes the right of Lake Erie and its watershed to 'exist, flourish, and naturally evolve'? How would a prosecutor, judge, or jury decide?" This was surprising in that courts commonly do adjudicate matters with scientific aspects. The court did not discuss any scientific or other sources available that could have been used to help interpret these terms. This decision potentially calls into question the legal system's ability to adjudicate scientific matters, or at least courts' willingness to do so in novel situations. On the other hand, this decision points to a way forward for rights of nature advocates: writing clearer or more scientifically descriptive laws may make it more likely that the laws will be upheld and given their intended effect by courts.

The right to evolve

Rights-of-nature laws and court decisions necessarily use many scientific concepts. One that recurs in many rights-of-nature laws is evolution and the "right to evolve" (Table 1). Few courts have yet interpreted this right, which makes scientific input as to how it might be interpreted even more urgent. Further, interdisciplinary examination of how evolution might be interpreted in different contexts may help drafters of proposed rights-of-nature laws in formulating this right. In this section we highlight some of the difficulties in understanding how this right applies to different types of natural entities and how it can be given effect. We then suggest how evolutionary biology can contribute to more clearly defining this new legal right.

Although scientific concepts are used widely in law, their scientific meaning, legal usage, and popular understanding rarely coincide precisely. Further, as many scholars have noted, scientific concepts and determinations are often contingent on social values to varying extents and contain varying levels of uncertainty; therefore recourse to science does not necessarily enable judges to apply objectively correct answers to legal questions (41, 42, 43, 44, 45). Legal decision-makers frequently must choose among differing scientific interpretations or interpret terms that have different meanings in different contexts. For instance, the US Supreme Court famously ruled in 1893 that tomatoes are legally considered vegetables, at least for the purpose of an import tax (46). The court acknowledged that botanically tomatoes

are fruit, but in the common language of the people they are vegetables and the common usage of tomatoes in salads rather than deserts was of decisive importance. In a contrasting legal context, when tomatoes are used in jams the EU Directive on fruit jams, jellies and marmalades, and sweetened chestnut purée classifies them as fruit (47). Although this classification agrees with the scientific definition of a fruit, it also reflects the popular idea of jams being made from fruit.

Evolution, like tomatoes, has many possible definitions. Although a broadly understood definition is something like "slow change over time," this is only the 7th (of 11) definitions of evolution in the Oxford English Dictionary (OED) (48). Number eight in the OED is the Darwin-inspired definition: "the transformation of animals, plants, and other living organisms into different forms by the accumulation of changes over successive generations; the transmutation of species." The other definitions include usage in dance, gymnastics, mathematics, chemistry, the military, and development (of societies, institutions, systems, products, arguments, organisms, and organs). There is a real possibility that different definitions of "evolve" in the "right to evolve" or "right to evolutionary processes" will be used in different legal jurisdictions. Further, many rights-of-nature laws specify the rights of lakes, ecosystems, and other entities to evolve. Group selection and evolution of nonhuman communities or ecosystems, though not uncontroversial, are recognized by some ecologists and evolutionary biologists (49), but this kind of evolution is not even included within the OED's definitions of the term.

Any or all these definitions can contribute to understanding what a "right to evolve" may entail, whether for a troop of monkeys, a population of wild rice, Lake Erie, or Pachamama. For example, a biological understanding of evolution may be applied to species or subspecies, whereas a more general "slow change over time" may pertain to rivers, lakes, and watersheds. The simultaneous application of multiple definitions of evolution is illustrated by the September 2021 decision of Ecuador's Constitutional Court regarding the rights of mangrove ecosystems (50).

In that case, the Court confirmed "that mangrove ecosystems are holders of the recognized rights of nature" and are entitled to "full respect for their existence and the maintenance and regeneration of their life cycles, structure, functions and evolutionary processes." As the Court noted, mangrove ecosystems are marine-coastal wetlands that provide habitat to many animal species and contribute to mitigating climate change. Explaining what it might mean to disrupt the evolutionary process of mangroves, the Court stated that "natural beings respond to long processes of permanent changes

that allow adaptation to the environment. The rupture of the elements that allow an evolutionary process would constitute a violation of the rights of nature." The court ruling implied that mangroves not only had the right to their evolutionary processes as species, which would require sufficient habitat and genetic diversity, but also had rights as ecosystems, implying that other species that relied on the mangroves as habitat should also have sufficient habitat and genetic diversity to evolve. This is consistent with current evolutionary thinking, which asserts that evolution is a property of populations, not individuals, and therefore requires a sustainable population size and sufficient within-population genetic diversity to enable adaptation to a changing environment (51, 52).

We note that the right to evolve may conflict with the right of a natural entity to exist or persist; over the history of Earth, change and extinction is the rule, not the exception: >99% of all species that have evolved in the last billion years have gone extinct (53). We are unaware of a rights-of-nature law that deals effectively with this contradiction or a challenge to a rights-of-nature law based on this conflict, but several cases have placed more emphasis on the right to exist rather than the right to evolve. Regardless, the timescales of existence, evolution, and natural extinction are potentially much longer than the human timescales that courts are used to dealing with and present an additional challenge for courts in making decisions that protect the rights of nature. This novelty makes scientific input even more important in enabling the legal system to meaningfully adjudicate rights of nature.

Although science alone cannot define what nature's rights mean in the legal systems that have incorporated them, science is a necessary component for understanding, for instance, evolutionary processes, ecological flows, speciation, extinction, and natural cycles, if and when nature or other entities are given rights to these processes.

Conclusions

The recent legal developments discussed in this Review demonstrate the importance of scientists to the implementation of rights-of-nature laws. The Constitutional Court of Ecuador has held that various entities, including the Los Cedros Forest and mangrove ecosystems, were rights holders, and that mining and fishing violated their rights. The testimony of ecologists, biologists and other scientists was essential to the Court's understanding of who these rights holders were and what industrial activities had violated their rights to their ecological functions. By contrast, other rights-of-nature laws have been held to be unconstitutional by courts, at least in one case because of the challenge of using scientific knowledge to protect rights. The 2019 Lake Erie Bill of

Rights, which overwhelmingly passed by a popular vote in Toledo, Ohio, was later held to be unconstitutionally vague on the grounds that it would be impossible to determine when Lake Erie's rights to "exist, flourish, and naturally evolve" were violated (54). Spain's Mar Menor law, though more detailed as to the rightsholder and rights than the Lake Erie law, may be headed for the same fate. The Spanish right-wing party Vox has challenged this law in Spain's constitutional court, alleging that it is unconstitutionally vague among other claimed shortcomings (55).

Because legal decision-makers often do not have the expertise to understand the rights and duties of nature, interdisciplinary research is urgently needed if rights-of-nature laws are to have legal meaning. By contributing to interdisciplinary analyses of different aspects of rights-of-nature laws before disputes arise, scientists can help contribute to the understanding and effectiveness of these laws. Although scientific uncertainty often cannot be eliminated (4), its reduction in turn reduces legal uncertainty and thus helps meet the objection by some judges and others that rights-of-nature laws are too vague to be applied.

There are many ways that scientists and scientific knowledge can help different legal systems understand nature's rights. One important way scientists can contribute is by being involved in litigation. Most rights-of-nature laws contain provisions allowing scientists or other members of the public to bring lawsuits. A successful lawsuit necessitates demonstration that the entity in question is protected and that its rights were violated—e.g., how its rights to ecological functions or evolutionary processes were impeded. These are clearly questions requiring scientific input and applications of ecological and evolutionary concepts. Scientists also can provide evidence in lawsuits to which they are not a party in many legal systems. *Amicus curiae* briefs and testimony from scientists were critically important in the Ecuadorian cases.

Many countries also allow the public, including scientists, to participate in environmental decision-making. Participation of scientists additionally may be built into the legal recognition of rights for nature: Grants of rights to natural entities often specify a process for ensuring that their rights are achieved, and many of these processes explicitly include a role for scientists. For example, the Mar Menor law established a scientific committee made up of "scientists and independent experts specialized in the study of the Mar Menor" (30). The scientists included in this committee are appointed, but these sorts of committees are another opportunity for scientists with relevant knowledge about particular rights-holding entities to be involved in understanding and upholding their rights.

Critically, even before a natural entity's rights are violated, scientists and legal scholars can help lay the scientific groundwork for these legal protections to function as intended. As rights-of-nature laws are new and many are untested, interdisciplinary scholarship applying both legal and scientific perspectives to explain concepts used in the legal protection of nature's rights is needed for the legal system to correctly adjudicate these rights. The availability of credible scholarly analysis of legal-scientific terms used in law would make these rights more tangible and accessible to the judges whose role it is to apply them.

Such scholarship can clarify what aspects of the laws require scientific input, and what aspects require other types of expertise. For example, the Mar Menor lagoon has the rights to be restored and to exist as a lagoon ecosystem. A legal scholar may use legal sources to explain to what level of restoration Mar Menor is legally entitled. However, it may not be clear from legal sources who decides the restoration baseline, and scientific input may also be necessary. A restoration ecologist could explain what may be required to achieve the required level of restoration but what measures are legally appropriate may also require input from social scientists and others, as humans are also considered to be part of the protected ecosystem.

Interdisciplinary scholarship is also of benefit to the many jurisdictions that are currently considering enacting rights-of-nature laws (56). As we have illustrated, the content of many of the terms used in rights-of-nature laws is unclear. Even though the legal definition of a term need not be the same as a scientific definition, scholarship exploring these concepts may help drafters of rights-of-nature laws choose terms that minimize conflicts between legal and scientific contexts, enabling new laws to be easier to apply and follow.

Another type of interdisciplinary scholarship that would assist the functioning of rights-of-nature laws would be the examination of the duties of nature. Although some of these laws, such as those in the Ecuador constitution, only grant rights for nature without corresponding duties, others, such as the New Zealand laws, equate nature to a legal person with both rights and duties. Indeed, uncertainty over liabilities and duties of nature was an impediment to implementing the Indian court decision assigning certain rivers legal personhood (2). Input from scientists is needed to understand what duties nature has (e.g., "ecosystem services") (57) and when nature may not be fulfilling these duties. By delineating, for example, the volume and quality of water provided by a river, scientists can help legal systems comprehend nature's potential legal obligations and understand what environmental protection measures may also be

legally required to ensure natural entities can continue to fulfil these obligations.

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Science and the legal rights of nature

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Editor's summary

Laws that establish legal rights for nature are being pursued in a growing number of countries to protect the environment. The success or failure of these rights-of-nature laws can depend in large part on how scientific concepts and expertise have been used to develop, interpret, and implement them. Epstein *et al.* reviewed key scientific aspects of rights-of-nature laws and the use of science in court decisions that have interpreted them. They examined the “right to evolve” to illustrate challenges in applying scientific concepts in rights-of-nature laws and identify some possible solutions. —Brad Wible

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