

VIEWPOINT

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Stewardship and management of freshwater ecosystems: From Leopold's land ethic to a freshwater ethic

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Abstract

1. In 1949, Aldo Leopold formalized the concept of the 'land ethic', in what emerged as a foundational and transformational way of thinking about natural resource management, biodiversity conservation, and stewardship in terrestrial systems. Yet, the land ethic has inherent linkages to aquatic ecosystems; Leopold himself conducted research on rivers and lakes, and freshwater ecosystems figured widely in his writing.
2. We reflect on the land ethic and other aspects of Leopold's scholarship to identify key messages that provide insight into the stewardship and management of freshwater ecosystems around the globe. We also frame what we call the 'freshwater ethic' around Leopold's legacy. Although Leopold could not have envisaged the stressors affecting modern aquatic ecosystems, his core principles remain salient. These apply not only to ecosystem protection, but also to the ethics of modern conservation economics, sustainability, and the protection of natural capital, in which lakes, rivers, and wetlands now figure prominently.
3. We identify key 'Aldo-inspired' recommendations for protecting and restoring freshwater ecosystems in the Anthropocene that emanate directly from his writings (e.g. adopt an ecosystem approach, identify win-win-win scenarios, recognize the irreplaceability of wild waters, and strive for freshwater optimism).
4. In an epoch where links between people and nature are becoming more explicit in environmental management, policy, and governance, we suggest that Aldo Leopold's work illustrates how inspirational, seminal thinkers have offered leadership in this domain. We contend that today there is still much that can be learned from Leopold, especially by the next generation of environmental practitioners, to ensure the effective stewardship of our aquatic ecosystems.
5. We submit that the adoption of a freshwater ethic in parallel with Leopold's land ethic will enhance the stewardship of the world's increasingly threatened fresh waters by raising the profile of the plight of fresh waters and identifying enduring actions that, if embraced, will help conserve and restore biodiversity.

KEYWORDS

Aldo Leopold, aquatic, conservation, fresh waters, natural resource management, stewardship

1 | INTRODUCTION

Aldo Leopold's *A Sand County Almanac* (Leopold, 1949) is considered to be among the most influential books ever written for those interested or involved in natural resource management, whether they are concerned members of the public or environmental professionals. The final essay of the book, titled 'The land ethic', is an environmental clarion call: it defines a moral responsibility to care for the natural world (Callicott, 1987). In many ways, the land ethic is the enduring lodestone of Leopold's conservation philosophy that has resonated for nearly three-quarters of a century (Norton, 1988; Newton, 2006; Callicott, 2013). *A Sand County Almanac* remains required reading for many natural resource and environmental management programmes in North America and beyond.

In the classroom and other fora, scholars (largely philosophers and ethicists, but also ecologists and economists) have deconstructed and interpreted Leopold's land ethic in diverse ways (including critiques: e.g. Heffernan, 1982), and have attempted to identify what he might have posited as the principles for 'success' (Callicott et al., 2009; Norton, 2011). There is considerable scope for interpreting, and reinterpreting, the land ethic in ways that are as relevant to contemporary conservation scientists and natural resource practitioners anywhere in the world as it was to Leopold in rural Wisconsin in the first half of the 20th century. For example, Leopold's early discussions in some ways relate directly to key concepts today, such as ecosystem resilience (Walker, 1995), ecosystem integrity (Karr, 1992), ecosystem restoration (Hobbs & Harris, 2001) and recovery (Kelly & Harwell, 1990), and land economics (Vaughn, 1999).

Using the term 'land' in the 'land ethic' means that it is often misinterpreted as a terrestrial philosophy alone. Yet Leopold's intent, undoubtedly, included the entire catchment and the living inhabitants of streams, rivers, lakes, wetlands, and other waters, in much the same way that many Indigenous peoples around the world use 'land' in an all-encompassing sense, akin to 'ecosystem'. Leopold states that 'The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land' (Leopold, 1949). To him, 'land' is, in the current ecological lexicon, an ecosystem in which people and other organisms live. Nonetheless, the apparent terrestrial connotations have long lingered, such that only a handful of freshwater scientists (such as Isaac Schlosser, Gene Helfman, Richard Merritt, and Brian Moss) have mused about the land ethic while drawing connections between their aquatic work and that of Leopold: for a treatment of stream fish ecology at a landscape scale, see Schlosser (1991); for a discussion of how Leopoldian thinking applies to the conservation of fish biodiversity, see Helfman (2007); and for an exploration of the effects of grazing on riparian and stream ecosystems, see Strand & Merritt (1999). The late Brian Moss (1943–2016) would often cite Aldo Leopold in his public lectures, also prefacing 'The Ecology of Freshwaters' (Moss, 2018) with Leopold's words. Most recently, Pister (2010), Piccolo (2012, 2017), and Piccolo, Unfer & Lobón-Cerviá (2017) have heightened the awareness of the relevance of the land ethic for freshwater scientists. Even the Aldo Leopold Foundation has featured freshwater content

relevant to conservation on their website (<https://www.aldoleopold.org/post/7-articles-read-world-water-day/>).

Despite these recent perspectives, to our knowledge there has been no attempt to consider how the land ethic and other aspects of Leopold's thinking interface with challenges facing contemporary scientists and practitioners working on freshwater ecosystem management, conservation, and restoration. This is somewhat surprising given the manifold threats that face freshwater biodiversity (Dudgeon et al., 2006; Harrison et al., 2018; Reid et al., 2019) and the numerous ecosystem services provided by healthy and productive aquatic ecosystems (Lynch et al., 2016; Kuehne et al., 2017). The concept of stewardship is one that certainly resonates within the freshwater conservation community (Fedler et al., 2001; Knuth & Siemer, 2004), and there are thus opportunities for Leopold's views to inform the development of a 'freshwater ethic'.

For the first time, we provide a comprehensive freshwater perspective on the land ethic (but for a marine perspective, see Auster et al., 2009). We acknowledge the extensive writings of various scholars (especially J.B. Callicott) on Leopold that adopt a largely philosophical approach; here, we adopt a pragmatic and practical focus on identifying how simple lessons from Leopold can contribute to our contemporary stewardship and conservation actions. Specifically, we reflect on the land ethic and other aspects of Leopold's scholarship to identify key messages that are relevant to inform the stewardship of freshwater ecosystems around the globe. We provide an overview of the direct and indirect links between Leopold's philosophy and freshwater ecosystems, considering how the core underpinnings of the land ethic are applicable to freshwater ecosystems. Within the Anthropocene, we recognize an urgency to engage our global citizenry to tackle complex problems; to that end, we conclude by identifying ten Aldo-inspired recommendations that we consider essential for a robust ethic for freshwater ecosystems, both today and in the future. Throughout, we also recognize that there are instances where Leopold's thinking holds less relevance to people today and may not be directly transferable without careful consideration of gender, racial, multicultural, and other equitability concerns. Here, it is not our desire, or place, to pass judgement. We also acknowledge that there are instances where we take liberties to extend our interpretation of Leopold's thinking, perhaps beyond his initial intentions. Leopold was not omniscient, so it is not unreasonable to reinterpret his writings through the lens of today. As noted above, this is not intended to be a philosophical treatment but rather a practical discussion that extends Leopold's idea more explicitly to the freshwater realm, given our collective belief that there is benefit from doing so. Although many would argue that Leopold's writings are timeless, it is our perspective that successive generations of learners and environmental practitioners may be losing touch with the land ethic, such that this article also serves as an accessible way, or a touchstone, to demonstrate the relevance of Leopold to the practitioners of today and tomorrow.

We present the 'freshwater ethic' as another way to reframe discussions about what is needed to conserve and restore freshwater biodiversity, given its dire state (Reid et al., 2019). Our intention is not to draw attention away from the land ethic, given the inherent

connections between people, land, and water, but we do see value in thinking explicitly about how Leopold's ideas relate to freshwater issues. Tickner et al. (2020) developed an emergency action plan to restore freshwater biodiversity that demands rethinking how we protect and manage freshwater resources. Fresh waters need and deserve the attention of the public and decision makers, and this is unlikely to occur without increasing collective awareness. It is our hope that by explicitly adopting a freshwater ethic we will be able to generate the public and political will needed to conserve and restore freshwater biodiversity.

2 | ALDO AND AQUATICS

Leopold was aware of the direct links between land and water: both as a natural resource practitioner and an avid angler (for photos of Leopold engaging in work and play in the waters of North America, see Figure 1). Some later aquatic scholars such as Noel Hynes further

elaborated on the connection between 'the stream and its valley' (including riparia, upland areas, and groundwater; Hynes, 1975) in a more nuanced and sophisticated manner. Nonetheless, Leopold was explicit about such connections in a simplistic way, emphasized by his journal entries during fishing trips (especially in the American Southwest; Leopold, 1953). His writings about the American Southwest made clear references to the effects of erosion and silt deposition on fluvial systems as a result of poor range management (Leopold, 1946). His colourful descriptions of time spent on the banks of the Rio Gavilan illustrated the ways in which a pristine catchment (one with ecological integrity) functioned. He reasoned that slow water run-off (as a result of intact land cover) regulated erosion and supported healthy stream habitat for native trout (Forbes, 2004). One of Aldo's sons, Luna Leopold, who often accompanied him on fishing and camping trips and who edited *A Sand County Almanac* for publication after his father's untimely death, went on to become a prominent fluvial geomorphologist, writing extensively about water management (Leopold & Wolman, 1960; Dunne & Leopold, 1978). He wrote *Water*

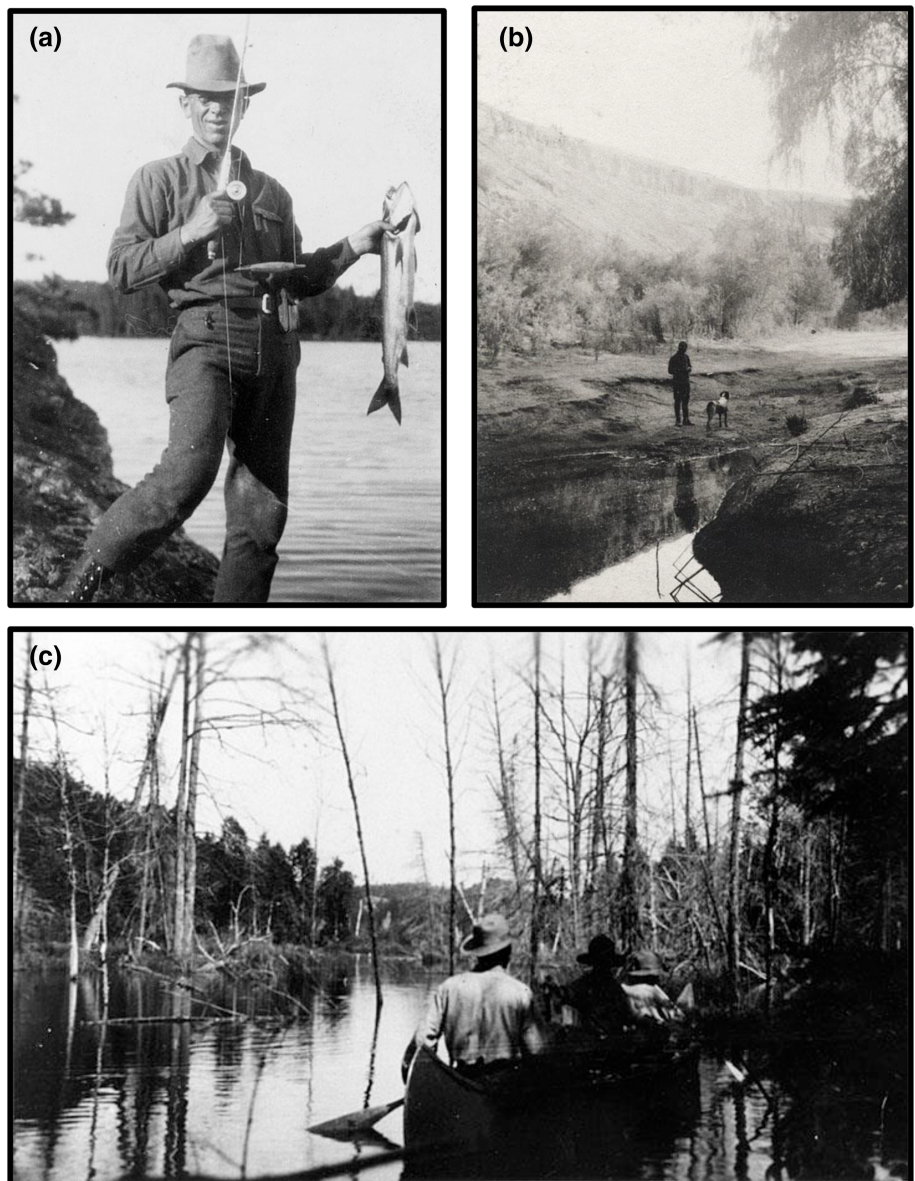


FIGURE 1 Images of Aldo Leopold showing him interacting with freshwater ecosystems in various ways: (a) Leopold with a fish captured in the International Boundary Waters Canoe Area, Quetico, Canada, in 1924; (b) Leopold observing the Green Lagoon along the Colorado River near Baja California during fieldwork in 1922; (c) Leopold together with sons Starker and Luna canoeing at the Boundary Waters in 1925. All photos are from the Aldo Leopold Archives at the University of Wisconsin (<https://uwdc.library.wisc.edu/collections/aldoleopold/>; <http://rightsstatements.org/vocab/UND/1.0/>)

— *A Primer*, a book arriving after the passage of the Clean Water Act in 1972, that served as an accessible guide for a generation attempting to navigate the complex intersection of environmental science and government bureaucracy. Another of Aldo's sons, A. Starker Leopold, went on to establish the University of California, Berkeley – Sagehen Creek Experimental Station in the Sierra Nevada Mountains of California. It was at Sagehen Creek that the first evidence began to accumulate to support wild trout management (Behnke, 2002). Among Starker's students was E. Phil Pister, a lifelong fish conservationist, founder of the Desert Fishes Council, and among the leaders of the successful fight before the US Supreme Court to save the desert pupfish (*Cyprinodon macularius*) from extinction (Callicott, 2017). To be clear, the fact that Leopold's sons had careers in aquatic science does not establish an inherent link between the Leopoldian land ethic and the aquatic ethic that we discuss here, but it is nonetheless interesting history and speaks to Leopold's broader legacy.

Aldo himself spent much of his career in the US Department of Agriculture Forest Service, which offered him an opportunity to consider the management of vast tracts of land (especially wilderness) criss-crossed with streams and rivers and dotted with ponds and lakes (Leopold, 1925). As such, most of his musings about wilderness and land management are equally relevant to the waters that traverse or are contained within public lands. In fact, some of the large wilderness spaces that were preserved by the Forest Service contain some of the longest-standing aquatic protected areas. The axiom that 'we all live downstream' was apparent to Leopold (1941) and is captured in a quote from one of his unpublished essays (Leopold, 1999): 'To those who know the speech of hills and rivers straightening a stream is like shipping vagrants — a very successful method of passing trouble from one place to the next. It solves nothing in any collective sense'. This axiom has since become the foundation for catchment-scale freshwater protected area implementation (Saunders, Meeuwig & Vincent, 2002; Bower, Lennox & Cooke, 2014) as well as for catchment restoration (Williams, Wood & Dombeck, 1997), both important aspects of the freshwater conservation toolbox.

Although Leopold never explicitly wrote about a 'water ethic', 'aquatic ethic', or 'freshwater ethic', a recent reflection by Lutz Warren (2010) explores the concept by providing a comprehensive analysis of some of Leopold's early fisheries writings. For example, in his early days, Leopold created a guidebook for the management of wildlife and fish in the Southwest (Leopold, 1915), which was one of the first formal frameworks in resource management. Leopold also became an early commentator on wilderness fish stocking and provided the foundation upon which the US Fish and Wildlife Service based their stocking (Lutz Warren, 2010). In 1918, he published a paper in the *Transactions of the American Fisheries Society* on the 'mixing of trout in western waters' (Leopold, 1918). He concluded that paper with the rather direct statement 'restock with the best adapted species, the native species always preferred', which suggests an appreciation for the role of local adaptation. The idea of trying to think about the relationship between fish production and the environment later became the focus of entire research programmes by notable scholars like Fred Fry (Fry, 1947) and Rolly Brett (Brett, 1971).

Pister (2001) provides a historical treatment of wilderness fish stocking and suggests that good ethical practice translates into good biological practice, basing some of his perspectives on the writings of Leopold.

Yet, paradoxically, in some of his other writings and correspondence, Leopold also advocated stocking non-native species (summarized well by Simberloff, 2012) that do not align with current considerations of invasive species. He went on to suggest that 'an empty [i.e. fishless] water is an idle resource' (Leopold, 1915, p. 235). Leopold argued that if a lake is fishless because of a severe winterkill event or fisheries collapse then such stocking may be merited, but fishless lakes serve as important habitats for other aquatic organisms such as amphibians (Knapp, Corn & Schindler, 2001; Pilliod & Peterson, 2001). Some scholars have considered the ethical aspects of invasive species control in the Laurentian Great Lakes using Leopold's framework (Sanford & Uglietta, 2010). Leopold had a particular disdain for introduced common carp (*Cyprinus carpio*), but at that time there was insufficient research available for him to understand the mechanism by which carp influence freshwater ecosystems (Simberloff, 2012). Given how contentious the topics of fish stocking (especially in wilderness areas) and invasive species have now become (Cucherousset & Olden, 2011), and with a much greater evidence base than was available in Leopold's time (recognizing that his thinking was not static, and evolved over time), it is not surprising that not all of his thinking about freshwater ecosystems aligns with our current ecological understanding. Nonetheless, he initiated conversations and avenues of inquiry that continue today.

3 | ALDO LEOPOLD'S ENDURING RELEVANCE

There can be no doubt that the world has changed substantially in the 70 years since the release of *A Sand County Almanac*, and there is a pertinent question about whether Aldo Leopold's world view still has currency. His formative and active years straddled two major world wars, the presidency of two Roosevelts, the Progressive Era, the Great Depression, and the New Deal. This was a time during which the societal context was one of accelerating industrialization, urbanization, and resource exploitation, to power growing economies, and political reform that challenged failures at home and abroad. Against this backdrop, Leopold's commitment to 'wilderness preservation' is understandable. Indigenous perspectives, of which Leopold seems to have been largely unaware, typically do not separate people from nature. Thus, there is continuing debate and increasing criticism regarding what is meant by 'wilderness' (Suchet, 2002; Sacre et al., 2019; also see <https://theyee.ca/Opinion/2018/09/28/Relations-Indigenous-Peoples-Europeans/>) and even about the viability of the very concept of wilderness (Callicott & Nelson, 1999). What are now exponentially greater pressures on natural ecosystems from population growth, climate change, and resource use have shifted the modern environmental movement somewhat away from wilderness preservation per se (note that the concept of 'no take' protected areas is consistent with wilderness preservation) towards Leopold's primary concern

in his Wisconsin years: achieving harmony between people and land. These stressors impinge particularly on the management of natural resources, biodiversity conservation, and the socio-economics of land-use decisions, the downstream consequences of which are large and accelerating for fresh waters (Harrison et al., 2018; Reid et al., 2019). Today, the need to protect ecosystems for their economic value, natural capital, and role in human life support have become important adjuncts to the ethical arguments for conservation: for resources as important as fresh waters, these needs are represented clearly in the ecosystem services paradigm (Ormerod, 2014; but see Dudgeon, 2014 for arguments for intrinsic value of aquatic biodiversity). Yet, in Leopold we find the sought-after concept of 'conservation economics' that valued ecosystem integrity, resilience, and resource use that operated within natural constraints and protected natural capital:

'The thing to be encouraged is the use of private land in such a way as to combine the public and the private interest to the greatest possible degree. If we are going to spend large sums of public money anyhow, why not use it to subsidize desirable combinations in land use, instead of to cure, by purchase, prohibition, or repair, the headache arising from bad ones?' – Aldo Leopold (1934).

This view has surprising relevance today, particularly in Europe, where the case for 'public spending for public benefit' has become a major political issue in the economics of river catchment management (Bateman & Balmford, 2018). We acknowledge that the concept of 'private lands' is a deeply colonial artefact, but private lands remain, nevertheless, a reality that resource managers and conservationists must deal with.

Inspired by the diverse writings of Aldo Leopold, we have used his direct quotes here to posit ten 'Aldo-inspired' recommendations for protecting and restoring freshwater ecosystems in the Anthropocene. We acknowledge that in our attempts to identify ecological theses we have committed an inherent disservice to the eloquent and poetic style of Leopold's writings. We encourage all readers of this essay to consult the original writings of Leopold as his style delivers a philosophical yet practical richness that we cannot aspire to represent here.

4 | TEN ALDO-INSPIRED RECOMMENDATIONS FOR FRESHWATER PROTECTION AND RESTORATION

4.1 | Adopt an ecosystem approach

'Harmony with land is like harmony with a friend; you cannot cherish his right hand and chop off his left. That is to say, you cannot love game and hate predators; you cannot conserve the waters and waste the ranges;

you cannot build the forest and mine the farm. The land is one organism.' – Aldo Leopold (1949)

Leopold's land ethic was founded upon his eco-evolutionary understanding of nature: he was a forester, game manager, and ecologist by trade. Leopold earned a master's degree from the Yale Forest School, he wrote the first major textbook on game management in the US (*Game Management*), and he served as President of the Ecological Society of America in 1946. He fully understood that ecosystems are built of complex and dynamic interactions of materials and energy, and his writings foreshadow the areas of academic study in ecosystem science as well as ecosystem stewardship. Such thinking remains highly relevant today as we move towards an ecosystem approach to the management of aquatic systems (Frissell & Bayles, 1996), or rather 'return to it' in that Indigenous management based on Indigenous ways of knowing pre-dated modern conceptions of ecosystem management and largely treated the environment as an interconnected whole (Berkes, 2018). An ecosystem approach extends beyond the physical (e.g. time and space) to include the process by which we consider and involve humans as parts of ecosystems and the management process (Long, Charles & Stephenson, 2015). Leopold was a contemporary of aquatic ecosystem ecologist Stephen Forbes, who was one of the first scientists to recognize the inherent interconnectedness of organisms and their environment (Forbes, 1887). It took decades after Leopold's passing before the 'harmony' – the interconnections – he thought about so much became fully ingrained in our thinking about resource management (Grumbine, 1994). Recently, Langhans et al. (2019) illustrated how an ecosystem approach to management in a freshwater context can increase public acceptance by introducing the consideration of human needs and aspirations into conventionally biodiversity-driven management approaches.

4.2 | Manage coupled social-ecological systems

'We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.' – Aldo Leopold (1949)

Leopold was also one of the first to recognize, in an ecological and Western scientific context, that humans are inextricably linked with the ecosystems to which they belong. In addition, only by explicitly treating these systems as part of our 'community', rather than as a 'commodity,' can these systems be managed sustainably. Leopold's perspective has surely influenced modern ecological theory, including current thinking on social-ecological systems (Berkes, Colding & Folke, 2001; Berkes, Doubleday & Cumming, 2012) and coupled human and natural systems (Liu et al., 2007a), and has undoubtedly permeated a number of global initiatives, such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Indeed, freshwater fisheries systems may be among the

best-known coupled systems, with examples of collapse when this dynamic is not respected and opportunities for effective adaptive management when it is (Lynch & Liu, 2014). Just north of the Leopold family's shack in Wisconsin, the US National Science Foundation has designated a Long-term Ecological Research unit in the North Temperate Lakes to examine the feedbacks between agriculture and tourism (Liu et al., 2007b). The dynamics of aquatic coupled social-ecological systems are complex but exploratory modelling can help to provide management with bounding constraints on strategies that are feasible and resilient to uncertainty (Carpenter & Gunderson, 2001). Our management failings often stem from our failure to recognize important characteristics of the coupled systems, reciprocal effects, feedbacks, thresholds, surprises, traps, or legacy effects (Liu et al., 2007a). Likewise, our management successes are often rooted in an acknowledgement of the complexities of human-aquatic system interactions, and a willingness to reassess approaches and to adapt to changing conditions. Through Leopold's 'community', we will best be able to manage our freshwater resources sustainably in a changing world.

4.3 | Acknowledge the limits to human dominance

'The government tells us we need flood control and comes to straighten the creek in our pasture. The engineer on the job tells us the creek is now able to carry off more flood water, but in the process we have lost our old willows where the owl hooted on a winter night and under which the cows switched flies in the noon shade. We lost the little marshy spot where our fringed gentians bloomed.' – Aldo Leopold (1953)

Naturally flowing rivers are among the most dynamic ecosystems on Earth; consequently, many rivers have been heavily modified to control flow to meet human needs while dampening or eliminating normal floods and droughts (Grill et al., 2019). But as Leopold astutely recognized, there are clear limits to the resilience of freshwater ecosystems to human use (see Folke, 2003). The human control of river flows is now nearly ubiquitous, with millions of dams worldwide that hold back nearly one-tenth of the water stored in natural lakes or about one-sixth of the total annual river flow into oceans. Despite providing many societal benefits, it is well recognized that river regulation has also caused considerable ecological damage and the loss of important ecosystem services valued by society. Now, more than ever, societies are grappling with the need to supply reliable and affordable water to growing populations, while at the same time not degrading freshwater ecosystems, nor disrupting their important ecosystem goods and services (Arthington et al., 2018). Leopold's thoughts remind us that although humans will continue to depend on freshwater ecosystems for water, food, and energy security, we must overcome the past over-exploitative tendencies of the dominant majority to ensure that the 'fringed gentians' can continue to bloom.

4.4 | Address underlying causes not symptoms of problems

'The practices we now call conservation are, to a large extent, local alleviations of biotic pain. They are necessary, but they must not be confused with cures.'

– Aldo Leopold (1949)

Leopold recognized that there was a tendency to focus on treating the symptoms of environmental problems rather than addressing the underlying cause; it is difficult to argue that we do not succumb to the same pitfalls to this day (Lindenmayer & Hunter, 2010). It is still the norm, particularly in industrialized nations, to focus on 'band-aid' solutions (Vörösmarty et al., 2010). In the context of catchments where surface water moves from the land to the stream, and from the headwaters downstream, failing to address the underlying problem ensures that the stressor will persist and, at some point, it is likely that the interventions being used to treat the symptom will fail. In one successful cause-focused approach, a project focused on restoring surface-groundwater interactions in rivers explicitly set out to address and alleviate the causes of degradation (Kasahara et al., 2009). Similarly, the 'urban stream syndrome' very intentionally recognizes the need for cures rather than treating the symptoms (Walsh et al., 2005). There is considerable scope to heed the early advice from Leopold and recognize that resources devoted to addressing symptoms of a problem represent short-sighted investments that 'must not be confused with cures' and will fail to ensure long-term success. Furthermore, this philosophy must extend to understanding the indirect causes – including economic growth and over-consumption by dominant human societies – to recognize that the ultimate solutions will require social, political, economic, and legal change.

4.5 | Acting even in the absence of complete understanding

'No matter how intently one studies the hundred little dramas of the woods and meadows, one can never learn all the salient facts about any one of them.'

– Aldo Leopold (1949)

A freshwater biodiversity crisis is upon us (Harrison et al., 2018), and environmental practitioners must apply effective interventions as rapidly as possible. Yet, there is rarely sufficient knowledge to act with the certainty that one would wish. Uncertainty is a reality within science that is especially apparent in the realm of ecology (Regan, Colyvan & Burgman, 2002) and is further amplified by the 'opaqueness' of aquatic systems. Some have argued that we can study a population or species to extirpation or extinction, respectively (Lawton, 1993), such that always asking for 'more' science is simply not realistic. On a daily basis, resource managers and practitioners are required to make decisions regarding conservation and management

actions, some of which may not in fact even be based on the best available scientific evidence (Pullin et al., 2004). There is now a movement towards evidence-based decision making (Webb et al., 2017), including in the aquatic realm (Cooke et al., 2017), where systematic reviews are used as the 'gold standard' of evidence synthesis (Sutherland et al., 2004). Yet, systematic reviews have not been conducted for every intervention and even where systematic reviews are completed, it is not uncommon to conclude that the evidence base is insufficient or weak, such that it is impossible to draw any conclusions regarding the effectiveness of interventions (for related resources, see www.conservationevidence.com and www.environmentalevidence.org). Does that mean that resource managers should not manage and that decision makers should not decide? As noted by Leopold, the only real certainty is uncertainty. At some point, one must act. This is not a plea for taking short cuts or ignoring evidence; rather, it is an embrace of a pragmatic perspective that requires decisions to be made with imperfect evidence and without 'all the salient facts'. A precautionary approach can be adopted in the absence of evidence (Cooney, 2004).

4.6 | Identify win-win-win scenarios

'Cease being intimidated by the argument that a right action is impossible because it does not yield maximum profits, or that a wrong action is to be condoned because it pays.' – Aldo Leopold (written 1947; published Leopold, 1991)

Leopold lamented economic excuses for failing to act in the best interest of the environment. In a world that is 'profit' driven, Leopold asks us to turn this argument on its head and look for solutions that can have economic *and* ecological rewards. These win-win scenarios are cases where strategic action can benefit all sectors involved. The most successful cases employ innovative approaches to minimize trade-offs between benefits to one party and costs to another. Ecosystem approaches to inland fisheries management are generally touted as the best-case win-win-win scenario: as a win for the fish by sustaining ecosystem productivity; as a win for the fisheries because the fisheries can flourish; and as a win for other water-resource users, benefitting from cleaner water (Beard et al., 2011). Clean water is a common linkage for win-wins in aquatic systems because clean water provides benefits to humans and often restores ecosystem function for aquatic organisms (e.g. Carson & Mitchell, 1993). Additional examples of win-win solutions for inland fish and fisheries are provided by Lynch et al. (2016). In the Anthropocene, we extend Leopold's vision to embrace and strengthen conservation partnerships that include public and private land and rights holders (Dombeck, Wood & Williams, 2003). Leopold frames this argument as a moral dilemma, and he uses it as a call to arms. Although this can still be (and often is) a motivation for aquatic ecologists, we are often better served by a willingness to work collaboratively with other sectors and groups to achieve desired ends. Win-win-win is a

winning strategy, in part, because it is cooperative and broadly beneficial. Increasing public awareness (i.e. voters and shareholders) about the importance of achieving win-win-win scenarios can be used as leverage to encourage the adoption of compromises in resource development. With more authentic partnerships and the cross-sectoral co-generation of knowledge, there will undoubtedly be greater buy-in and, consequently, better payout.

4.7 | Wild waters are irreplaceable

'Perhaps our grandsons, having never seen a wild river, will never miss the chance to set a canoe in one.'
– Aldo Leopold (1949)

Musing that a wild river lost will not be missed, Leopold ironically highlights that, indeed, it will be a major loss to future generations. Protected area designation remains among the most relevant of all of Leopold's insights: today, the Convention on Biological Diversity targets the protection of 17% terrestrial and inland water habitats and 10% marine habitats (Secretariat of the Convention on Biological Diversity, 2010). Furthermore, there is growing scientific evidence that we will need to protect up to 50% of aquatic habitats to ensure sustainable flows of ecosystem services and avert widespread ecosystem collapse. Yet, the establishment of marine and freshwater protected areas lags behind terrestrial habitat protection (Hermoso et al., 2016; Loury et al., 2018). Recently, a group of leading conservation biologists has warned that 'global conservation policy must stop the disappearance of Earth's few intact ecosystems' (Watson et al., 2018). The value of wilderness for freshwater habitats, for example, can be seen from the tremendous ecosystem services provided by free-flowing rivers (Auerbach et al., 2014), including 'the chance to set a canoe' in them and Alaska's sustainable wild salmon fisheries, recognized by some as a model for sustainable fisheries management (Cline, Schindler & Hilborn, 2017).

4.8 | Relationships with nature are essential

'Like winds and sunsets, wild things were taken for granted until progress began to do away with them.' – Aldo Leopold (1949)

As contemporary human society successively replaces wild places (e.g. forests, grasslands, and fresh waters) with infrastructure and development linked to urbanization and resource extraction (Foley et al., 2005), we are becoming increasingly disconnected from nature (Kareiva, 2008). This 'progress' is particularly apparent among the youth, who are spending an increasing amount of time in virtual realities and contexts and less and less time outdoors: the so-called 'extinction of experience' (Pergams & Zaradic, 2006; Soga & Gaston, 2016). Given that time spent in nature is fundamental to our connection to it (Kals, Schumacher & Montada, 1999) – and that

today's youth represents tomorrow's stewards of nature – it is imperative that we prioritize protecting the connection between people, particularly children, and nature now (Soga & Gaston, 2016). As emphasized elsewhere in this article, fresh waters are in an increasingly perilous state and establishing strong connections between humans and freshwater systems represents a real opportunity for instilling Leopold's land (and aquatic) ethic in the next generation before 'progress ... [does] away with them'. A very positive signal in terms of human relationships with nature is the recent focus within the conservation community on relational values (RVs) by IPBES (Pascual et al., 2017), although again RVs have long characterized Indigenous relationships with the natural world, pre-dating our modern conceptions of RVs. The RV concept (i.e. values that arise from a relationship with nature that may encompass a sense of place, well-being, and cultural, community, or personal identities; Chan, Gould & Pascual, 2018) has the potential to supplement the traditional ecosystem services approach by acknowledging the meaningfulness of human–nature relationships in providing for a good life.

4.9 | Embrace freshwater optimism

'We shall never achieve harmony with the land, any more than we shall achieve absolute justice or liberty for people. In these higher aspirations the important thing is not to achieve but to strive.' – Aldo Leopold (written 1938; published Leopold, 1953)

Leopold recognized that human development was a necessity, and that conflicts between humans and nature would continue. Yet, he also struck an optimistic albeit pragmatic tone, which is particularly striking today, as many seek to define what it means to achieve a 'good' Anthropocene (Bennett et al., 2016; Dalby, 2016). To be clear, Leopold was unsure whether humanity could change its ways, but he certainly ceded that we must try. And to try, one must hold some level of optimism. Indeed, there is a growing recognition for the need to develop alternatives to the 'sky is falling' narrative (Beever, 2000). The concepts of hope and optimism have emerged in recent decades (Swaigood & Sheppard, 2010; Garnett & Lindenmayer, 2011), more broadly within conservation science, but are particularly important for aquatic systems. For example, the #oceanoptimism movement (Kelsey, 2016) has seen investments in understanding the role of public perceptions in framing ocean conservation issues (Jefferson et al., 2015). In the freshwater realm, alarm bells continue to ring regarding the grim state of biodiversity and expanding threats (Harrison et al., 2018; Reid et al., 2019), yet there are also reasons to be optimistic (Geist, 2015) and make efforts to better engage the public as allies (Cooke et al., 2013). Embracing the optimism and tenacity of Leopold's 'higher aspirations' will be useful for further advancing and realizing incremental progress in freshwater conservation, but this perspective must also be balanced with Leopold's inherently more pessimistic thinking. Indeed, that tension between optimism and pessimism remains today.

4.10 | Appreciating the diverse values of freshwater biodiversity

'Our ability to perceive quality in nature begins, as in art, with the pretty. It expands through successive stages of the beautiful to values as yet uncaptured by language.' – Aldo Leopold (1949)

Freshwater biodiversity provides a broad variety of valuable goods and services for human societies, many of which are irreplaceable. Yet, as Leopold suggests, measuring the value of biodiversity as simply the monetary sum of derived goods and services is inappropriate, because intangible factors such as beauty, life-fulfilling values, and spirituality are of extreme importance. The appreciation of the various values of biodiversity for humankind – ranging from utilitarian to ethical – is essential (Kellert, 1997). For instance, the aesthetic values (i.e. physical appeal and beauty) of freshwater environments have been long unappreciated by many because they are unseen. The vast majority of their inhabitants (e.g. fish and invertebrates) remain 'out of sight, and largely out of mind' (e.g. because of turbid water, thick macrophyte cover, or stygofauna in groundwater), and there is generally an absence of the megafauna (but see Carrizo et al., 2017) that are so common in the marine realm; this lack of public awareness of freshwater life may ultimately limit freshwater conservation as a popular cause or movement (Monroe et al., 2009; Boon & Baxter, 2016). Leopold argues that the direct experience of nature's beauty is priceless, and here we extend this argument to images and visual media. Photographs and videos can play a critical role in visually connecting freshwater ecosystems to their would-be stewards. Images are capable of conveying information and evoking emotion at a glance, and are generally more intuitive, more quickly assimilated, and often more memorable than verbal description (Monroe et al., 2009). Looking ahead, a better appreciation of the diverse values of freshwater biodiversity 'as yet uncaptured by language' will undoubtedly contribute to a more inclusive freshwater ethic.

5 | SYNTHESIS AND CONCLUSION

We are now in an epoch when links between people and nature are increasingly explicit in environmental management, policy, and governance. Concepts such as natural capital, ecosystem services, nature's contributions to people (Díaz et al., 2018), and natural resource management are prominent drivers of decisions in weighing environmental exploitation with environmental protection. There is value, then, in considering the contributions made by individuals who have shaped current philosophical positions on these topics through their inspiration, pioneering thoughts, and leadership. Among these figures, Aldo Leopold continues to stand out. A sign of the universal and timeless appeal of Leopold's ethic is the biocultural conservation ethic of Rozzi (2015, 2018), which draws explicitly on Leopold and recognizes the widespread traditions among Indigenous peoples around the world of human cohabitation with and indivisibility from nature,

precisely as Leopold wrote: 'that men are only fellow voyagers with other creatures in the odyssey of evolution' (Leopold, 1949, quoted in Rozzi, 2018).

Yet, much has changed. For example, we are now in an era of attempted reconciliation between settlers and Indigenous peoples in North America, where the dominant majority is beginning to awaken to the long-standing injustices borne by the Indigenous peoples of these lands and waters at the hands of settler colonists (Adams & Mulligan, 2003). Early (Leopold-era) resource management and conservation failed to adequately or respectfully include Indigenous perspectives and rights. Recent studies have revealed that imperilled species fare as well on Indigenous lands as they do in formal protected areas (Schuster et al., 2019), emphasizing that there is still much to learn from the knowledge systems of Indigenous peoples and from working in direct, fair, and equitable partnership with them. In addition, we now acknowledge other elements of social awareness (e.g. gender, sexual orientation, and race) that are absent in a perspective that only recognizes 'grandsons' as beneficiaries. This is to say that although we still have much to learn from Leopold, there are other voices, knowledge, and perspectives that should be embraced by conversations about contemporary and future natural resource management – something that we have only recently recognized and begun to do (Gould et al., 2018). Although beyond the scope of this article, these are also important sources in framing conservation today, reflecting a more inclusive perspective than those presented in Leopold's writings. For example, Tallis & Lubchenco (2014) advocate inclusive conservation, Green et al. (2015) call for diverse voices and approaches, and Gould et al. (2018) emphasize the need to diversify conservation. We explicitly encourage the inclusion of works like these – and other essential readings on Indigenous wisdom and scientific knowledge (Kimmerer, 2013; Berkes, 2018) – alongside examinations of Leopold's writings in curricula and classrooms to provide a more nuanced discussion on inclusive approaches to the conservation and management of freshwater ecosystems.

Here, we have considered how Aldo Leopold's 'land ethic' is relevant to the conservation, management, and stewardship of freshwater ecosystems, or what we term the 'freshwater ethic'. What is remarkable is that the messages that we drew from some of the most important and beloved quotes from Leopold mirror those emerging from contemporary discussions about what is needed to achieve healthy and productive freshwater ecosystems (Lapointe et al., 2014). This is perhaps not surprising given that Leopold was a holistic thinker (Coufal, 2000). Although the 'land' ethic has terrestrial connotations, Leopold was intimately aware of the connections between land and water (i.e. catchment), as we have noted above. We contend that Leopold probably deserves more credit for his influence on applied freshwater science (for examples, see Box 1). We also suggest that *A Sand County Almanac* is as relevant to trainees in freshwater science as to those in forestry, wildlife management, conservation science, environmental ethics, and rangeland ecology. More importantly, his writings are also valuable to members of the public and the diverse stakeholders that interact with the natural world. Leopold was well aware of the fact that humans were both the cause of and the

solution to most environmental problems. Wouldn't it be great if *A Sand County* was as common in the classroom as *A Tale of Two Cities*, *The Great Gatsby*, *To Kill a Mockingbird*, or *Wuthering Heights* (to name a few)?

BOX 1 Examples of how some freshwater ecologists and practitioners were influenced by the writings of Aldo Leopold

On 2 December, 2018 one of the co-authors (SJC) tweeted the following from his @SJC_fishy Twitter account: 'Hey freshwater ecologists/practitioners – did Aldo Leopold and his writings influence you in any meaningful way? I am looking for connections between Leopold and the aquatic realm.' Here are some representative anonymous responses from Twitter in December 2018:

- I'd say Leopold's succinct, eloquent presentations of basic ecological ideas went a long way to transforming me into a conservation-centred aquatic ecologist
- Leopold's essay *Thinking Like a Mountain* was my first introduction to trophic cascades, a concept that I (along with many other aquatic ecologists) apply every day
- Leopold's writings prompted a desire to improve my communication skills. Land and water are inextricably connected; what happens on the land impacts the aquatic environment
- *A Sand County Almanac* was part of what shaped my overall conservation ethic and philosophy. One of the waters I routinely survey (Les Cheneaux Islands) was where he spent some of his boyhood summers. I think of him whenever I'm working there
- While *A Sand County Almanac* was foundational, his work in the Coon Valley Watershed was influential in my interests in aquatic biology, fisheries, and cooperative conservation
- I had to read *Odyssey* for my PhD exams and write about it in the context of freshwater ecology. I think about it constantly since then
- *A Sand County Almanac* and other writings by Leopold were fundamental in shaping my views of conservation and land mgmt. I was very surprised to learn recently that *A Sand County Almanac* was not standard reading in Canadian Fish and Wildlife undergrad courses

Leopold was both wise and visionary, influencing many scholars and contemporary environmental stewards through the paradigms that he developed. We, like many others in our field, have been significantly influenced by Leopold's conservation philosophy and hold that 'when we see land as a community to which we belong, we may begin

to use it with love and respect'. Yet, we suspect he would be underwhelmed by the extent to which we have embraced what he advocated so eloquently. Throughout Leopold's writings and our ten Aldo-inspired recommendations, we see alignment with global conservation initiatives. For example, IPBES places a strong emphasis on indirect drivers as the ultimate cause and source of solutions for environmental degradation, not unlike the 'pains' and 'cures' discussed by Leopold (see recommendation 4.5), and not unlike his repeated critique of treating the more-than-human world as a commodity and limiting conservation motives to the economic sphere (see recommendations 4.2, 4.8, and 4.9). His son, Carl Leopold, notes that the bioethical principles celebrated by the land ethic can be rapidly altered or destroyed by social dysfunctions such as greed, poverty, and war (Leopold, 2004) – ideas that were not explicitly raised by Aldo Leopold. In short, the 'freshwater ethic' needs to be updated given the existence of distinct and equally valid world views, including diverse perspectives, in recognition of the need for more equitable and socially just approaches to the conservation and management of natural resources, where people of marginalized and colonized communities have an opportunity to have their voices heard and their right to participate is upheld (Green et al., 2015; also refer to the United Nations Declaration on the Rights of Indigenous Peoples, https://www.un.org/development/desa/indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf).

The dystopian future that some envisage in response to the term 'Anthropocene' would be such a manifestation of that social dysfunction. To that end, and in the quest for a 'good' Anthropocene (Dalby, 2016), it will be important to recognize the inherent links between humans and freshwater ecosystems and that many of the solutions will not be about ecology but rather about human behaviour: as individuals and as a collective society. These ten Aldo-inspired recommendations (recognizing that we may or may not have interpreted them in exactly the same way Leopold intended) should flavour our thinking as we develop effective partnerships, engage the global citizenry, and generate the public and political will that is necessary to reverse the decline of freshwater biodiversity and maintain the diverse and important ecosystem services generated by freshwater ecosystems. To that end, it is time to embrace a 'freshwater ethic'.

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only and does not imply endorsement by the US Government. The Anthropocene currently has no formal status in the Divisions of Geologic Time and is not recognized by the US Geological Survey: the use of this term here is informal.

CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

All authors contributed to idea generation, writing and editing.

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