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PERSPECTIVE ESSAY

The conservation and restoration of freshwater ecosystems and biodiversity can be enhanced with ecopracticology

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Abstract

Freshwater ecosystems are among the most degraded on the planet and there is strong evidence that freshwater biodiversity is in precipitous decline. To that end, there is urgent need to conserve and restore freshwater ecosystems and biodiversity in order to ensure that freshwaters continue to yield diverse ecosystem services. Although there is some scientific uncertainty about how to do so, there is recognition that practitioners play a particularly important role. Practitioners work on the front line with a focus on implementing various environmental interventions and therefore can bridge the gap between knowledge and action in a unique way given their extensive experience in the field. Yet, practitioners do not know it all, nor do they have access or time to keep up-to-date on the growing scientific evidence base. Ecopracticology (i.e., the study of socio-ecological practice and the ensuing body of knowledge) is, therefore, a useful construct for thinking about the ways in which different disciplinary domains and ways of knowing to intersect to generate or refine knowledge and evidence needed to implement actions that benefit people and the environment. Ecopracticology is inherently grounded in that most practitioners are environmental stewards who deliver solutions alone and/or in partnership with diverse stakeholders and rightsholders. Ecopracticology, therefore, represents both the challenge and opportunity for addressing the freshwater biodiversity crisis. Here we consider what ecopracticology has to offer, and strategies for realizing the pathways that enable knowledge exchange and implementation for on-the-ground/in-the-water practitioner actions benefitting conservation and restoration of freshwater ecosystems and biodiversity. If this concept is embraced and practitioners are supported and championed, there is potential for rapid advances that are desperately needed to conserve and restore freshwater ecosystems and biodiversity.

Keywords Biodiversity · Freshwater · Knowledge exchange · Management · Practice

1 Status of freshwater ecosystems and biodiversity

Humans have dramatically altered ecosystems and are responsible for unprecedented losses of biodiversity (Vitousek et al. 1997; Díaz et al. 2019). Although this is a global issue spanning regions, realms and taxa, it is perhaps most extreme and dire for freshwater ecosystems and biodiversity (Harrison et al. 2018). For example, the WWF Living Planet Index reports that freshwater biodiversity has declined by ~ 84% since the 1970s (https://livingplanet.panda.org/freshwater). Humans depend on freshwater ecosystems for drinking water, irrigation, sanitation, food, and electricity (among other ecosystem services), so it is unsurprising that much human development is centred around rivers and lakes (Konar et al. 2016). Although the threats facing freshwater ecosystems and biodiversity are many (and growing), the most commonly cited threats are pollution, fragmentation, habitat degradation, invasive species, and over-exploitation of water, biological resources, and aggregate resources (Dudgeon et al. 2006; Reid et al. 2019). Given the dire state of freshwater ecosystems and biodiversity, and urgency for addressing this crisis, Tickner et al. (2020) developed an "emergency recovery plan". If embraced

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regionally, nationally, and internationally by diverse actors, the plan has the potential to halt further declines and restore freshwater ecosystems and biodiversity. However, there are inherent challenges with implementing the plan that is rooted in issues related to knowledge exchange, evidence availability and use, political will derived from societal concern, and institutional barriers, among others (Twardek et al. 2021).

2 Implementation challenges are pervasive

Although implementing the emergency action plan for freshwater biodiversity will require the efforts of many, the so-called "front line" for this task is environmental and ecological practitioners. Watershed planners, restoration ecologists, stewardship coordinators, and others that work for governments and NGOs are engaged in day-to-day activities and decision-making that will dictate the extent to which the emergency action plan will succeed (Twardek et al. 2021). This is not to devalue the work of scientists, policymakers, and communities which are all key players, but it is the practitioners who connect those other actors and focus on implementation (Maas et al. 2019). For more than a decade, scholars have argued that we need to focus on implementing conservation actions (Meijaard et al. 2014). Although there are still knowledge gaps that exist related to freshwater conservation (see Harper et al. 2021; Maasri et al. 2022), a lack of scientific knowledge is often not the driver behind inaction. Practitioners are typically educated through formal institutions and may have additional professional development, but they also hold much experiential knowledge that they have gained from their lived experiences.[1] From successes and failures, they have the potential to learn on the job and make refinements. In many ways, these individuals are engaging in ecopracticology which involves combining pragmatic ways of knowing with more formal study of socio-ecological problems and solutions (Xiang 2019). Ecopracticology is particularly salient to freshwater biodiversity conservation given the scale of the issue (from local to global), the urgency, and the need for solutions.

Here, we consider the potential role of ecopracticology as a pathway for conserving and restoring freshwater ecosystems and biodiversity (see Fig. 1) and present six actions that are necessary to realize this opportunity. This alone will not be a panacea but is an important step in supporting practitioners with their important tasks and ensuring that the best knowledge is used to implement conservation solutions. We submit that if practitioners are supported and championed, there is potential for rapid advances that are desperately needed to conserve and restore freshwater ecosystems and biodiversity (Table 1).

3 A case for ecopracticology

By definition, "ecopracticology is the study of socio-ecological practice and the ensuing body of knowledge" with a focus on socio-ecological practice as the object of study, a commitment to generating a body of knowledge about socio-ecological practice, and pragmatic ways of knowing (Xiang 2019). Ecopracticology spans the entirety of the knowledge-application spectrum—working to improve socio-ecological outcomes through more effective interactions between knowledge (and evidence) and application. These concepts have been most commonly applied in environmental planning (Forester 2020) but also have relevance to the freshwater biodiversity crisis. Ecopracticology is about moving from theory to practice—closing the so-called theory–practice gap (Cooke et al. 2021a). This gap is widely recognized as a major impediment at implementing effective conservation (Cook et al. 2013). From a practitioner perspective, what matters is that the work they do is supported (both in terms of resources and by society) and that it has impact (i.e., it meaningfully benefits biodiversity and ecosystems). From a more fundamental disciplinary perspective, what matters is that we[2] learn how to best support practitioners and equip them with the best evidence to make better decisions (Dubois et al. 2020). Ecopracticology does just that—studying the processes behind the practice (e.g., the interface between knowledge generation and application) to ensure impact. In some ways, ecopracticology is a form of implementation science (Rapport et al. 2018). Given that freshwater biodiversity is imperiled and past efforts to arrest declines have largely failed (Albert et al. 2021), there is a level of desperation to get things right. Hence, ecopracticology is a useful and timely development. To be clear, the concepts behind ecopracticology are not new. Rather, ecopracticology is a logical label for this area of inquiry and practice that effectively bridges the work of knowledge generators/holders and practitioners.[3]

[1] We acknowledge that practitioners may themselves be Indigenous and holders of Indigenous knowledge. As two settler authors it is not our place to elaborate on the role of Indigenous peoples in the space of ecopracticology but hope that others with relevant positionality undertake such scholarship.

[2] The "we" in this context is the community of knowledge generators (academics, researchers), evidence synthesizers, and institutions that employ and support practitioners (e.g., government bodies, NGOs, industry).

[3] We acknowledge that practitioners come from different backgrounds. Some individuals hold positions where they are both scientists and practitioner. For the purpose of this essay we have focused

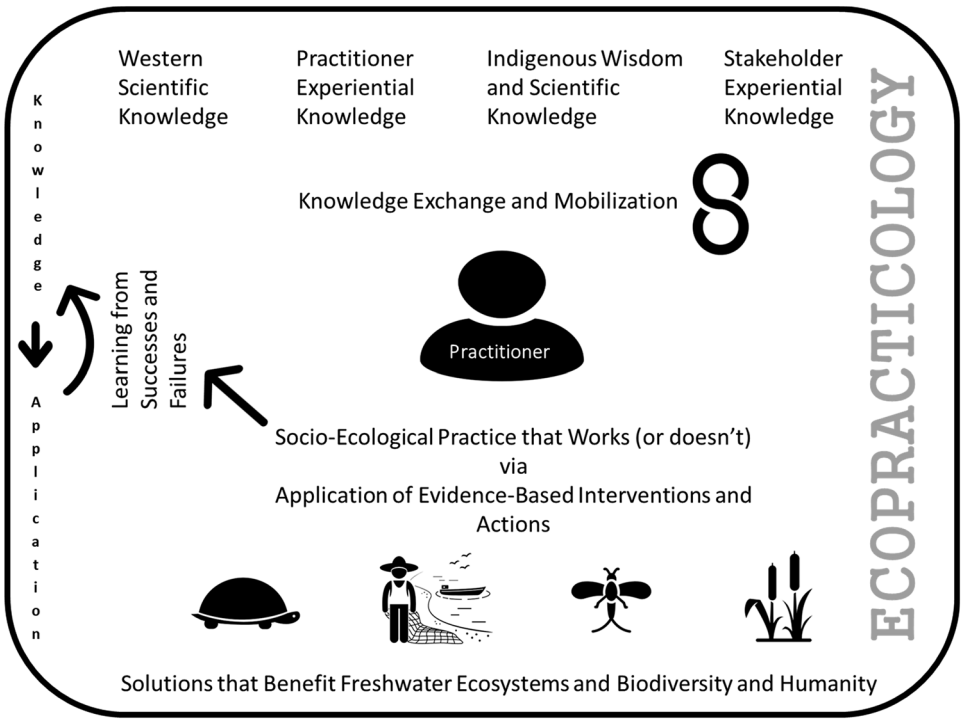

Fig. 1 Ecopractiology as a construct for conserving and restoring freshwater ecosystems and biodiversity. Xiang (2019) conceptualized ecopracticology using a figure that involved concentric circles. Here we revisit that structure and present it in a more linear manner (with feedbacks). We also acknowledge were other key papers or concepts influenced the structure. Beginning at the top, there are a variety of knowledge domains and forms of knowledge. All of these are valid and collectively can be used to inform practice. However, knowledge moves in complex ways and there is an intermediate space (termed as the "mediation sphere" by Nguyen et al. 2017) where knowledge exchange and mobilization occurs. That is visualized as an "infinity" symbol illustrating the complexity of knowledge movement. Although not discussed in this paper, knowledge brokers can play a role in bridging knowledge generators/holders and users (Kadykalo et al. 2021b). The infinity symbol is set vertically to emphasize movement of knowledge from the top to the bottom and vice versa. Moving down on the figure is the practitioner who we have centred in this paper. The practitioner applies various knowledge [ideally in an evidence-based framework as per Sutherland et al. (2004) and discussed in a freshwater context in Reid et al. (2022)]. Practitioners learn along the way—including through formal monitoring and collaboration with those who study the outcome of interventions (i.e., scientists). Successes and failures both feedback to build the evidence base and inform future interventions. At the end of the day, these collective processes (which ARE "ecopracticology") are what is needed to achieve meaningful improvements in freshwater conservation and restoration

4 Actions needed to realize the benefits of ecopracticology

4.1 Practitioners need to be equipped with the best evidence

Ensuring that practitioners are equipped with the best evidence requires an understanding of bias arising from the evidence base and various forms of evidence synthesis as well as an assumption that they have access to the evidence in a reliable and useable form. Evidence comes in many forms. Similarly, all evidence is subject to various types and levels of bias. What is key when it comes to practitioners making decisions (e.g., which interventions to use in a given context) is that they are considering the best available evidence (of all forms) yet also realizing the potential for the sample of gathered evidence to be biased. This requires adjusting their belief in the results based on a weight of evidence. For example, it is possible to make selective use of studies that align with a particular worldview, thus confirming the perspective already held by a practitioner. Moreover, not all studies are of the same quality such that the ability of a study to rigorously address a given objective may be limited by experimental design (e.g., lack of comparator or replication) or sample size. To address these limitations, it is possible to conduct comprehensive systematic reviews that are intended to minimize bias (see Haddaway and Pullin 2014; Cooke et al. 2017 for aquatic overview). Such approaches are used in the health care realm with the goal of making better

Footnote 3 (continued)

on the many practitioners that truly focus on the practical implementation of actions and interventions related to freshwater ecosystems.

Table 1 Examples that highlight how six actions needed to embrace ecopracticology can yield tangible improvements in the practice of freshwater conservation. We acknowledge that the examples are ones that the authors are familiar with so are decidedly Canadian in focus

Actions Needed to Realize the Benefits of Ecopracticology	Brief Examples Highlighting How these Actions Have Been Applied in Freshwater Conservation
Practitioners need to be equipped with the best evidence	Unfortunately the concept of evidence-based decision-making has been excluded from most textbooks and not well covered in most undergraduate training programs in conservation. Although not specific to freshwater systems or practitioners, there is a growing movement to improve training of students on these topics and to also provide professional development courses. Downey et al. (2021) provide an overview of key resources for training in evidence-based conservation with a particular emphasis on practitioners
Evidence must be provided in accessible and useable formats	An evidence-based toolbox to support practitioners in making decisions about freshwater conservation interventions was developed for use in Canada (Reid et al. 2022). The tool provides detailed information on both the reliability and relevance of evidence syntheses using a colour-coded system. The toolbox is online and highly visual and tailored specifically to the Canadian context. Information is provided in different layers such that practitioners can dig deeper if they so desire. The tool was developed through extensive consultation with practitioners to address their specific needs
Knowledge held by practitioners needs to be harnessed and shared	Aquatic Habitat Toronto is an umbrella organization that brings together researchers and practitioners from many different agencies with the goal of providing opportunity for dialogue and sharing around the restoration of aquatic habitats in and around Toronto, Canada (see Piczak et al. 2022b for overview). These activities have led to the co-production of new knowledge and on-the-ground (actually on-the-boat) collaborations. The practitioner knowledge increases the relevance of the work and provides additional insight into findings (Piczak et al. 2022b). Practitioner experiences are also shared among organizations
Failures matter as much as successes but we need to fail forward	Dams impede migration of fish such that it is common for fishways to be installed in an attempt to restore connectivity. One general failure of the fish passage practitioner community has been attempting to adapt fish passage criteria for well-studied salmonids to the many lesser-studied species (Mallen-Cooper and Brand 2007). Learning from failures has been important to realize that there is need for biological design criteria specific to a given fish assemblage and that not all fish behave like salmonids
Social science process-based research is needed to improve implementation	Social science interviews focused on fish and wildlife practitioners in British Columbia, Canada, identified barriers to their application of new research as well as local and Indigenous knowledge (Kadykalo et al. 2021a). Knowledge of barriers and knowledge consumption behaviours provides opportunities to overcome those issues to improve implementation
Freshwater practitioners need to be supported and championed	In the scientific community it is common to provide awards to researchers, yet less common are opportunities to celebrate and recognize the outstanding contributions of practitioners. Providing opportunities to showcase freshwater practitioners and the important work they do is but one way to champion and acknowledge their efforts. Fortunately, there are a growing number of examples such as Conservation Ontario which gives out the Latornell Awards that tend to focus on practitioners and their innovation and commitment to watershed conservation (http://www.latornell.ca/)

health care decisions and also have merit in an environmental context (Pullin and Knight 2001). However, formal scientific studies are but one form of evidence. For example, Indigenous knowledge keepers or elders also have scientific knowledge derived from millennia of observations and passed along through stories. There is growing recognition of the importance of bridging knowledge systems by using approaches such as "two-eyed seeing[4]" (Bartlett et al. 2012;

[4] Two-eyed seeing is the concept that Western science and Indigenous knowledge lenses can both be used to simultaneously understand or view any given issue, problem, or solution. Neither is supe-

Reid et al. 2021). Given that Indigenous-managed lands often have higher biodiversity than lands managed by other governments (Schuster et al. 2019), there is opportunity for enhancing western-based management strategies. Other actors such as stakeholders (e.g., anglers, kayakers, bird watchers, community members engaged in citizen science) can also be holders of knowledge that could be useful for practitioners. Practitioners themselves are also holders of knowledge based on their experiences (see below). All of these evidence sources spanning different forms have value but there can be challenges with bringing them together in a cohesive and cogent manner. What is clear is that practitioners are not using the full suite of evidence available to them when making decisions (Pullin et al. 2004; Young et al. 2016a). That needs to be changed given that western-based scientific, Indigenous and local/stakeholder knowledge are all important in different ways (Kadykalo et al. 2021a).

4.2 Evidence must be provided in accessible and useable formats

It is well known that two of the factors that impede practitioner use of (new) evidence is accessibility and useability (Kadykalo et al. 2021b; Roche et al. 2022). With respect to accessibility, many practitioners do not have access to peer-reviewed literature databases (Sunderland et al. 2009; Sutherland and Wordley 2017). Assuming they have time to search for and locate potential evidence, it is often behind paywalls (Veríssimo et al. 2020). Open access formats, which are becoming increasingly common, have the potential to empower practitioners in ways that have not been possible before (Fuller et al. 2014) which is important given that practitioners value science (Piczak et al. 2022a). However, just because evidence is accessible does not mean that it is useable (Stephenson et al. 2017). To that end, there is need for the development of resources such as dashboards and "toolboxes" that serve as a one-stop-shop for relevant information presented in formats that allow practitioners to rapidly assess evidence and use it to inform their practice. For example, Reid et al. (2022) developed a toolbox specific to Canada that enables practitioners to assess the relevance and reliability of different evidence sources specific to various freshwater interventions via two rubric-based scores. Accessible through a web portal (www.aquatichabitat.ca), this bespoke toolbox is intended to serve practitioners and make it easy for them to access and use the best and most reliable evidence. Similar tools could be developed for other regions, particularly given that implementation of actions at regional scales will differ from that outlined in the emergency recovery plan. The Collaboration for Environmental Evidence generates plain language summaries of systematic reviews and maps (see https://environmentalevidence.org/policy-briefs/) and Conservation Evidence has developed subject-wide evidence syntheses (see Sutherland and Wordley 2018). Downey et al. (2022) used case studies to identify principles for ensuring sufficient and relevant evidence is transmitted to practitioners. Notably, researchers may not be the most appropriate individuals to communicate findings to practitioners. Individuals with expertise in knowledge brokering, knowledge translation and mobilization can serve key roles in ensuring that evidence is provided to practitioners in useable formats (Kadykalo et al. 2021b).

4.3 Knowledge held by practitioners needs to be harnessed and shared

As noted above, practitioners have a wealth of knowledge gained from their experiences. Yet, that knowledge is often not shared such that it fails to contribute to the overall evidence base, or to benefit other practitioners. There is need for systems to harness the experience of practitioners so that such knowledge can be curated and shared. Practitioners are about implementation and not necessarily building the evidence base. There is need for a change in culture where the work done by practitioners is embedded within research or monitoring programs. Similarly, there is opportunity to develop mechanisms for practitioners to share their observation so they can be formally recorded. Several journals have moved towards creating new types of "journal" articles where practitioners can share case reports or observations based on their work (e.g., Socio-Ecological Practice Research; Ecological Solutions and Evidence; Restoration Ecology; Conservation Science & Practice), but there are other opportunities for sharing. For example, this can come in the form of co-production where researchers and practitioners work hand-in-hand and learn from each other (Beier et al. 2017). Indeed, collaborative efforts that include elements of a participatory approach have great potential to improve knowledge exchange between researchers and practitioners. Co-production is particularly relevant to issues related to aquatic systems given the many different actor groups that depend on or interact with freshwater ecosystems (Cooke et al. 2021c). This can also be through networking opportunities at joint sessions at workshops or symposia that bring together scientists and practitioners. This would likely require dedicated funding given that practitioners are often not afforded the same travel budgets or flexibility as researchers. However, there is also a growing number of opportunities to use technology for virtual interactions. There is also need for practitioners to be able to share their experiences with other practitioners—not just regionally but internationally (again—a great use of online platforms).

Footnote 4 (continued)

rior to the other—they are both equally valid and when considered together they can yield novel insights.

More informal networks of practitioners focused on issues or interventions are needed to facilitate knowledge exchange.

4.4 Failures matter as much as successes but we need to fail forward

Nature is complicated and not all interventions intended to conserve or restore freshwater ecosystems or biodiversity will work. In fact, failure is common in the environmental sphere. However, the only real failure is when the learning opportunities that arise from failure are ignored. The so-called "failing forward" approach (Maxwell 2007) is highly relevant to conservation of freshwaters. There are certainly opportunities to learn from published failures (see Catalano et al. 2019) but there are presumably many (many!) examples of failures that are not published. The challenge is ensuring that the inherent adaptive learning that comes with being a practitioner yields lessons that can be shared more broadly within and beyond their community. Ecopracticology is well positioned to provide guidance on how to best capture and share lessons learned from both successful and failed interventions.

4.5 Social science process-based research is needed to improve implementation

A productive area of research would be social science studies focused on understanding barriers to implementation and action—a central aspect of ecopracticology (Xiang 2019). The theory–practice divide has been well studied and in doing so has identified best practices for narrowing or bridging the divide (Lauber et al. 2011; Young et al. 2016b; Nguyen et al. 2017). Additional research is needed to better understand how the aforementioned actions can be best supported and to identify other actions that are not covered here. Much of the research that has been done on the theory–practice divide and implementation related to both freshwater conservation and conservation more broadly has focused on developed countries (Milner-Gulland et al. 2010; Darwall et al. 2011), with robust governance structures, scientific capacity and resources to engage in freshwater interventions. The reality is that freshwater biodiversity issues are global and the issues that constrain progress likely vary across regions (e.g., in some developing countries resources and capacity may be limited and in countries with weak or unstable governance, there can be issues with corruption). Understanding the barriers that create the divide between knowledge and action is necessary if we are to bridge said divide. A call for studying practitioners and the processes that could enable their work may seem redundant but is essential for ensuring that issues are identified and overcome forthwith, so that practitioners, the front-line workers addressing the biodiversity crisis, can be effective in their work/actions. There are many examples in health care (Krzyzanowska et al. 2011) and education (Odom 2009) where social science efforts focused on practitioners have been transformative in achieving better outcomes.

4.6 Freshwater practitioners need to be supported and championed

It is easy to forget about the important work being done by practitioners. Media is often full of the latest scientific discoveries and tends to celebrate the scientists. The stories we really need to celebrate are those of the practitioners to further mobilize them in this effort (He et al. 2021; Twardek et al. 2021). For example, we could do a better job of celebrating successes that represent meaningful improvements in freshwater ecosystems and biodiversity (Cooke et al. 2013). This can be done by identifying "heroes" and including them in narratives about freshwater conservation via social and traditional media. Similarly, although we have centred practitioners as THE key players in making change (as per Twardek et al. 2021), the reality is that it will take many parties working together. Those tasked with creation of high-level policy or funding such work, the researchers studying such interventions, rightsholders, and stakeholders must all work together in supporting practitioners and in working collaboratively to address the freshwater biodiversity crisis. Finally, relative to marine and terrestrial conservation, freshwater stories are rather uncommon (Cooke et al. 2013; He et al. 2021). Creating opportunities to celebrate the good work being done by practitioners (often in partnership with community volunteers) is essential for showing the public and politicians what is possible so that investments in the conservation and restoration of freshwater ecosystems and biodiversity not only continue but are embraced by all as a priority. The "showcase" articles in the international journal *Socio-Ecological Practice Research* provide a forum for highlighting the roles that practitioners play in implementing conservation solutions.

5 Putting it together for freshwater conservation

There is broad acknowledgement that freshwater ecosystems are degraded, and freshwater biodiversity in crisis (Harrison et al. 2018; Albert et al. 2021; Arthington 2021). Ecopracticology is a useful construct for thinking about the ways in which different disciplinary domains (e.g., ecology, social science, hydrology) and ways of knowing intersect, and therefore ecopracticology offer potential to enhance freshwater conservation and restoration. Ecopracticology is inherently grounded in that most practitioners are environmental stewards (Cooke et al. 2021b) who deliver solutions

alone and/or in partnership with diverse stakeholders and rightsholders. In this way, ecopracticology represents both a challenge and an opportunity for addressing the freshwater biodiversity crisis. Scholarship on ecopracticology combined with creating more opportunities to embrace evidence and share successes (and failures) could be transformational for freshwater ecosystems which are in a dire state. If this concept is embraced and practitioners are supported and championed, there is potential for rapid advances that are desperately needed to conserve and restore freshwater ecosystems and biodiversity. Moreover, if ecopracticology can be leveraged to address the freshwater biodiversity crisis, then its potential for other issues and realms is limitless.

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Declarations

Competing interests Cooke is on the editorial board of the journal Socio-Ecological Practice Research but was not involved in handling this manuscript. No other competing interests are reported.

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