Our failure to protect the stream and its valley: A call to back off from riparian development

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Abstract: Decades ago, Dr Noel Hynes eloquently summarized the inherent interconnectedness of a stream and its valley and made the case that human alteration of the valley would have direct negative consequences for freshwater systems. Currently, the freshwater biodiversity crisis extends across all continents and demands urgent attention from environmental planners, practitioners, and policymakers to protect streams and their valleys. As we work to slow losses of freshwater biodiversity and restore freshwater ecosystems, it is time to revisit the important messages from Hynes. One of the most obvious and immediate actions that could be undertaken is to "back off"—that is, to limit human activity and new development in floodplain and riparian areas immediately adjacent to freshwater systems, including streams, rivers, lakes, and wetlands, while minimizing impacts and risks in areas with existing development. From reducing erosion and flood damage to maintaining cool water temperatures, filtering pollutants, protecting critical habitats, and enabling lateral connectivity, intact riparian zones mitigate many of the threats that degrade freshwater ecosystems. There has been much research to identify optimal setbacks and buffer-strip widths to protect against harm. As such, in many areas, our ability to protect the stream and its valley is not limited by natural science but rather our failure to consistently apply floodplain and riparian regulations and the absence of political will. We are too quick to trade off the environment for short-term economic development. In areas that are already developed, solutions are more complicated but, in many cases, represent a key priority for healing damaged ecosystems and for addressing economic and social risks of vulnerable development. We need to redefine our relationship with freshwater ecosystems, and the first step is to back off and give freshwater ecosystems the opportunity to heal while ensuring that as-of-yet intact riparian areas continue to support freshwater resiliency. In doing so, we will also gain climate adaptive benefits, given that maintaining intact riparian areas is an effective nature-based solution.
Key words: Biodiversity, climate change, floodplain, fresh water, management, riparia

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INTRODUCTION

History matters—The Stream and Its Valley

In 1974, Dr H. B. Noel Hynes delivered the Elgardo Baldi Memorial Lecture titled "The Stream and Its Valley" at the Societas Internationalis Limnologiciae meeting. His lecture was subsequently published (see Hynes 1975) and, to this day, represents a seminal paper in freshwater science. Hynes stated, "We may conclude then that in every respect the valley rules the stream" (p. 12). He went on to further state, "It is also clear that changes in the valley wrought by man may have large (sic. detrimental) effects" (p. 12). It follows, then, that if we are to protect the stream and its biota, we must also protect the valley. The ideas raised by Hynes (also see Hynes 1970) are now well accepted, and interfaces between terrestrial and aquatic systems are regarded as hotspots for ecosystem processes (Gregory et al. 1991, Krause et al. 2017). We submit that over the past 50 y we have failed to protect the valley, despite the warnings and guidance from Hynes and others (see Yates and Bailey 2006), and in doing so, our freshwater ecosystems have suffered.

Today, we face a freshwater biodiversity crisis (Dudgeon 2010, Strayer and Dudgeon 2010, Harrison et al. 2018, Arthington 2021, Su et al. 2021). Freshwater ecosystems are the most imperiled systems on the planet as a result of many persistent and emerging threats (Dudgeon et al. 2006, Reid et al. 2019). The World Wildlife Fund's Living Planet Index (LPI; https://wwf.panda.org/discover/knowledge_hub/all_publications/living_planet_index2/) tracks the status of vertebrate populations and reports that those in freshwater systems have declined >80% relative to 1970 levels—ironically, the same decade when Hynes was writing and speaking about the stream and its valley. In fact, according to the LPI, freshwater biodiversity has declined faster than in either marine or terrestrial ecosystems. The state of freshwater biodiversity is so dire that recent efforts have focused on developing an emergency action plan to not simply stop the decline but to reverse it (Tickner et al. 2020). The action plan is bold and focuses on high-level policy actions that are urgently needed to address the many threats facing freshwater biodiversity. Similarly, a recent warning to humanity regarding the freshwater biodiversity crisis identified a number of actions that need to be undertaken to save freshwater biodiversity (Albert et al. 2021).

Yet, upon reflection, there is something missing from both of these calls, and that something is consideration of the ideas first raised by Hynes. Quite simply, the single biggest way to protect and restore freshwater ecosystems is to give them the space they need. We need to physically separate our activities and infrastructure from floodplains and riparian zones. It is apparent that what we do in the floodplain and riparian zone has dramatic effects on ecosystem structure and function, yet we continue to develop these areas. Would we be facing a freshwater biodiversity crisis if we had maintained setbacks and buffers between watercourses/waterbodies and human development and activities? Yes, both aforementioned papers (i.e., Tickner et al. 2020, Albert et al. 2021) emphasize the need to minimize or prevent habitat alteration, but neither explicitly states the need to stop putting human infrastructure in floodplains and riparian zones.

We submit that an immediate way to benefit freshwater biodiversity and freshwater ecosystems is to back off—to get human infrastructure and damaging activities out of the valley. This tactic inherently means no new development in these areas but will also mean removing existing infrastructure where possible. Of course, what Hynes meant by the "valley" is not entirely clear. Indeed, it is impossible to know whether Hynes was referring to the entirety of the basin (i.e., the watershed or catchment) or just the floodplain and its associated riparian system. From the perspective of human development, it would be unreasonable in most instances to apply a basin-wide prohibition on development or land-use change. As such, for the purpose of this perspective article we focus on the floodplain and the associated riparia. In some incised systems, the floodplain would be rather narrow, whereas in some lowland areas, particularly in the wet tropics and prairies, floodplains may extend tens of km away from the river channel.

On the need to back off and give nature some space

The historical basis for settling directly on water was access to water for transportation, milling, drinking, and bathing (Macklin and Lewin 2015). An analysis of human settlement relative to the availability of fresh surface waters revealed that the global median population distance to water is 3 km to large water bodies (Kummu et al. 2011). There are certainly some parts of the world where there is continued dependence on surface waters for drinking, but that does not always require that infrastructure be positioned directly on the water's edge. In other areas of the world, people can access freshwater through the ground. The availability of water from groundwater aquifers in the United States has been associated with a trend towards settlement away from surface waters since the industrial revolution (Fang and Jawitz 2019). Increased proportions of individuals living in urban areas may give the illusion of reductions in impacts to surface waters, but in many urban areas such water sources are filled in (wetlands; Davidson 2014, Mao et al. 2018) or constrained in concrete channels (Cooke et al. 2020). Pumping of groundwater has also reduced river flow and depleted wetlands such that development away from the valley will not remove all impacts to the stream (de Graaf et al. 2019). Moreover, even in rural areas there can be extensive land-use change in areas adjacent to freshwater systems as a result of agriculture, which completely alters streams and wetlands (Dudley and Alexander 2017). Collectively these impacts are regarded as persistent and expanding threats to freshwater biodiversity (Martinuzzi et al. 2014, Reid et al. 2019) and

are magnified by other stressors, such as climate change (Davis et al. 2015). The irony is that protecting the stream and its valley also protects against climate-change impacts (Davies 2010). In fact, effective management of riparian areas is a key tool to minimize human and environmental risk of climate heating.

We recognize that it is not uncommon to restrict development in floodplains, but the basis for such rules tends to be flood protection and insurability rather than concern for freshwater biodiversity (Holway and Burby 1990, Burby 2001). What if we set and enforced clear criteria for protection on waterfront and riparian development? Rarely have we had the courage to do so. Usually, short-term financial interests drive development activities, and environmental impacts of developments are considered individually during assessments—not how they cumulatively add up with one more dock, one more building, one more reach of cleared riparian area, or one more hardened shoreline. Unfortunately, this short-term view fails to recognize the immense value of the ecosystem services provided by intact and healthy freshwater ecosystems and freshwater biodiversity. Indeed, riparian zones are among the most productive and valuable natural resources in the world because they support numerous ecological processes (e.g., high species diversity, wildlife habitat, nutrient recycling; Naiman and Decamps 1997, Bentrup and Hoag 1998, Pusey and Arthington 2003, Naiman et al. 2010).

Keeping development out of floodplains and ensuring a buffer between human activity and freshwater systems provides many obvious benefits for freshwater ecosystems and biodiversity. For example, vegetated and natural shorelines reduce erosion relative to shorelines cleared of vegetation (Simon and Collison 2002), reduce soil loss from upland areas through filtering (Cooper et al. 1987, Uusi-Kämppä et al. 1996), and can diminish damage from floods by dissipating hydraulic energy (Gurnell 2014, Gurnell et al. 2016). Moreover, keeping infrastructure out of floodplains reduces the likelihood of losses to infrastructure and human life (Dixon et al. 2019). Intact (or restored) riparian zones can also improve water quality in a variety of ways, including by providing shade to maintain cool water (Parkyn et al. 2003) and dissolved oxygen while decreasing turbidity (e.g., Collins et al. 2013) and non-point source pollutants (Lowrance et al. 1985), such as nutrient inputs (Osborne and Kovacic 1993, Barling and Moore 1994, Vought et al. 1995) and road salt (Entrekin et al. 2019). Intact riparian areas can also help to filter toxins (Daniels and Gilliam 1996, Parkyn and Davies-Colley 2003) and minimize aquatic light pollution (Longcore and Rich 2004).

Natural and intact riparian areas also provide broad benefits as nature-based solutions (Dalwani and Gopal 2020). They serve as critical habitats for freshwater-dependent organisms (Richardson et al. 2010), contribute allochthonous inputs (Vannote et al. 1980, Richardson and Sato 2015), and enable lateral connectivity (Amoros and Bornette 2002). In addition, intact riparian areas provide resilience for temporary perturbations (e.g., floods; Biggs et al. 2012) and may serve as hotspots for climate change adaptation (Seavy et al. 2009, Capon et al. 2013). Recent research from Brazil revealed that freshwater biodiversity was directly related to loss of riparian vegetation and proposed a 50-m setback, at minimum, and to consider even larger setbacks in some situations given the heterogeneity of biodiversity responses to riparian vegetation loss (Dala-Corte et al. 2020). Riparian areas are also key for source water protection because they allow recharge of groundwater (Abell et al. 2019), thus helping to mitigate water scarcity issues.

This summary is not exhaustive (see Naiman et al. 2010 for an entire book on the ecology and conservation of riparia) but emphasizes the diverse benefits that arise from having intact riparian zones. It is also worth noting that although the details behind these mechanisms and relationships have been elucidated in the last few decades, Hynes provided a lucid synthesis of ideas about the connections between rivers and their drainage basins in the 1970s. Those ideas expanded aquatic ecology to the landscape scale and stimulated new lines of research into nutrient cycling, the importance of allochthonous inputs, and the effects of land use on aquatic systems. This makes our lack of action on riparian protection and restoration since then even more egregious. Here we offer concrete suggestions that can be implemented by both the scientific community and those engaged in decision making around freshwaters (Fig. 1).

Co-benefits from backing off

As a result of repeated and catastrophic flood events, we are starting to push people and infrastructure back from the water's edge (Holway and Burby 1993). Not only does backing infrastructure out of riparian areas and floodplains reduce the likelihood of infrastructure damage or loss of human life, it also allows freshwater systems to function in more natural ways, where floods are not thought of as catastrophes but rather part of the cycle of natural renewal. Rather than waiting for inevitable flood events, being proactive and starting to redesign cities where we do not live on water, but rather near water, is only sensible. In that sense, this approach addresses one of the key issues raised by Dudgeon (2010), where he argued for the importance of maintaining both structure and function in aquatic ecosystems. Indeed, these win–win scenarios (benefits for biodiversity and people) are exactly what is needed to benefit nature and people. An initiative in The Netherlands known as "Room for the River" (https://www.dutchwatersector.com/news/room-for-the-river-programme) does just that—it addresses flooding issues while at the same time enhancing biodiversity through nature-based solutions and extensive floodplain restoration (Klijn et al. 2018). Giving rivers the room they need to behave as rivers do is good for people and good for nature.

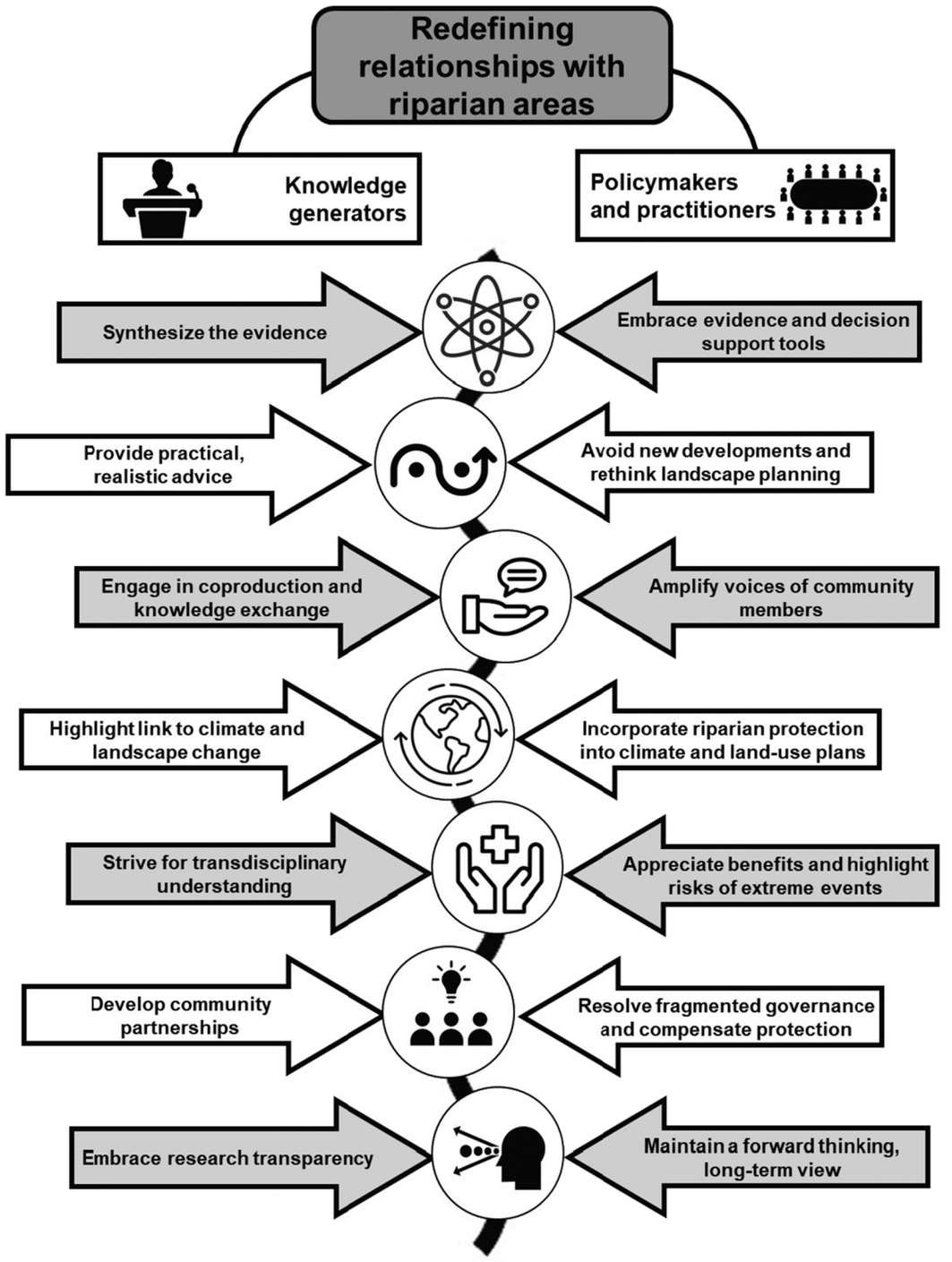

Figure 1. The role of scientists and policymakers in redefining our relationship with riparian areas.

Do we have the evidence to act?

There are certainly some aspects of freshwater biodiversity conservation where more evidence is needed before one can act (Harper et al. 2021, Maasri et al. 2022). With respect to riparian protections, we will undoubtedly learn more as researchers apply new research techniques and forge more interdisciplinary collaboration. Quantifying the areal extent of streams of different orders and the extent to which they have various forms of riparian protections would help to quantify the global scale of the challenge. Examining cases

of successes and failures could also be useful, particularly with respect to implementation and adherence to planning policies that protect riparian areas and freshwater biodiversity.

However, none of these gaps impede our ability to restrict development in riparian areas. The evidence base is substantial, clear, and compelling—numerous syntheses document the consequences of riparian alterations on freshwater biodiversity (Brinson and Malvárez 2002, Naiman et al. 2010, Opperman et al. 2010, Strayer and Findlay 2010, Tockner et al. 2010, Poff et al. 2011), and even more syntheses consider the benefits of different widths of riparian zone setbacks or buffer zones on ecosystem structure and function with outcomes that span biotic and abiotic components (Norris 1993, Wenger 1999, Hickey and Doran 2004, Correll 2005, Lovell and Sullivan 2006, Liu et al. 2008, Zhang et al. 2010, Kroll and Oakland 2019, Lind et al. 2019). It is also known, but less recognized, that in many cases restoration does not require massive capital investments (but see the Sponge City Program for an example of a solution with high capital costs; Xia et al. 2017) and that the economic costs of maintaining infrastructure are sometimes even larger than the costs of removing them (e.g., Baker et al. 2015). There are also great economic costs associated with the loss of ecosystem services when rivers and riparian areas are misused, limiting human benefit from these areas (Sweeney et al. 2004). Indeed, neglect of these areas has contributed to the water-quality crisis, biodiversity crisis, and food insecurity among many other threats facing society, and these crises can only be expected to worsen with climate change (Hanjra and Qureshi 2010, discussed in Albert et al. 2021).

Despite syntheses conducted both globally and on a regional basis that provide policymakers and practitioners with the knowledge, tools, and motivation needed to act, there is a clear knowledge–action (or science–practice) gap (Cook et al. 2013) related to riparian zone management. The reasons for this pervasive knowledge–action gap in conservation and environmental management are many (Cvitanovic et al. 2016) and are beyond an in-depth analysis here. Nonetheless, it is well known that decision makers appreciate evidence syntheses (such as the many listed above) over individual empirical studies, given that they provide weight of evidence to guide them (see Thomas-Walters et al. 2021), and their use does lead to better decisions and conservation outcomes (Walsh et al. 2015). So why is the extensive natural science knowledge in these syntheses dismissed? Development generates tax dollars and, in the short term, benefits society and the economy, which often puts immense pressure on decision makers who tend to seek public support over short-term periods (i.e., election cycles; Metrick and Weitzman 1998). This short-term focus is troubling given that most environmental problems require long-term solutions (Gale et al. 2021). Further, when policies are put in place, efforts are needed to ensure that they lead to meaningful action at the local scale (Twardek et al. 2021). The scientific community is well aware of the interconnectedness between the environment, society (including health and wellness and nutritional security), and the economy, such that when ecosystem services are impaired because of poor management decisions, we all lose (Postel and Carpenter 1997, Mace et al. 2012, Dodds et al. 2013). However, we could all win with a strategy that accommodates nature.

RECOMMENDATIONS

Here we present recommendations (Fig. 1) directed towards both scientists and policymakers, intended to enable actions that will protect freshwater ecosystems by backing off from riparian development.

For knowledge generators

Synthesize the evidence Package the enormous literature into well-grounded syntheses—we have a lot of scientific knowledge, but it is often diffuse across the literature.

Provide practical, realistic advice Provide concrete and practical advice on actions but remain realistic—landscapes are not going to return to pristine states. Provide case studies to learn from that fit the local environment.

Engage in coproduction and knowledge exchange Embrace coproduction approaches that engage decision makers, rights holders, and stakeholders in all phases of research (from idea generation to application). Engage in bidirectional communication and knowledge exchange. Ensure research findings are shared with practitioners and policymakers, as well as the broader public, to build support for backing off from riparian development.

Highlight the link between riparian zones and climate Highlight the importance of healthy riparian zones in fostering climate adaptation (nature-based solutions) and building resilience, including to other forms of land-use change.

Strive for transdisciplinary understanding Build connections to improve our interdisciplinary and transdisciplinary understanding of riparian areas and their protection and restoration. Build links between economists, social scientists, and the insurance industry, among others, to understand dimensions of cost, culture, equity, and other factors associated with ecosystem management and managing change, as well as collective efforts to protect and restore freshwater biodiversity.

Develop community partnerships Identify and engage the right bridging organizations or individuals (i.e., knowledge

brokers). Bring community groups on board early. Share scientific knowledge (e.g., synthesized knowledge, see above) with groups that often don't have access to scientific literature or expertise while also listening and engaging their knowledge and capacity as stewards.

Embrace research transparency Articulate the trade-offs. In some areas, riparian restoration can have crucial impacts on flows. In others, there are huge economic, social, or equity-related impacts of change (positive or negative). Make sure this information is propagated so that good, integrated decision making is supported.

For policymakers and practitioners

Embrace evidence and decision support tools Follow the scientific consensus (e.g., evidence syntheses) and use established decision support tools to enact protection. Although there may be variation in recommendations regarding buffer widths, impacts, and benefits, there is consensus that riparian areas need protection and that protection will enhance biodiversity and water quality, as well as reduce water-related risks.

Avoid new developments in riparian areas, be flexible, and rethink landscape planning Do not negate the easy wins—prevent new development in riparian areas now. Addressing existing development is certainly more challenging and costly. Seek creative solutions that may involve rethinking how we design urban areas (e.g., the sponge city movement). Urban planners will play a key role in identifying urban configurations that benefit nature and people.

Amplify voices of community members Amplify and elevate the voices of community members working to protect riparia and floodplains. We can learn a lot from Indigenous ways of knowing and knowledge held by other stakeholders.

Incorporate riparian protection into climate and landscape plans Commit to the consideration of the riparian area in climate-change vulnerability assessment, strategic flood assessment, cumulative effects assessment, watershed and landscape planning, source water protection planning, and other areas where riparian development intersects with societal goals, environmental impacts, and planning, among others.

Appreciate the economic and health benefits and highlight the risks of extreme events See the economic (benefits of nature and more) and health benefits of protecting the stream and its valley as a win–win solution for nature and people. Living in vulnerable areas becomes less appealing when their vulnerability (e.g., to floods) is known.

Resolve fragmented governance and compensate landowners for protection Work to resolve fragmented governance, fragmented planning processes, and weak governance that has allowed such issues to arise. Enhance awareness, coordination, and capacity among management agencies. Make flood risk assessment and land-use planning processes more transparent and accessible. Set aside funds to compensate landowners for protecting, re-naturalizing, or restoring riparian habitat and floodplains as part of climate-change resilience planning and green infrastructure.

Maintain a forward-thinking, long-term view Be cognizant of infrastructure lock-in and future ramifications of decisions made today. Current decisions secure risks of the future, and those risks are often not held by those making infrastructure decisions—they are held by society via insurance costs and by future generations.

Recommendations in action

There are examples where knowledge generators (including knowledge holders) and end users (e.g., decision makers, planners, practitioners, stewards) have come together in an attempt to achieve what we have outlined here. One example that exemplifies many of our recommendations is efforts in the Murray–Darling Basin of Australia. The basin covers ~ 15% of Australia's land area (>1 million km^2) and is located in the southeastern portion of the country. It is largely lowland and is characterized by slow-moving water. The area is heralded for its biological productivity and diverse array of life, which has evolved over 60 million y (Shiel et al. 1998, Mooney and Tan 2012). Over the last few centuries, the basin has been subject to expansive agricultural development, which has included land clearing and installation of various irrigation infrastructure, including dams. The basin is also home to some 2 million people. Flow alterations and water taking have altered freshwater biodiversity directly and indirectly (e.g., through impacting the health of riparian vegetation; Doody and Overton 2009). Freshwater fish in particular have been negatively affected, leading to many species being listed on the International Union for Conservation of Nature's Red List (https://www.iucnredlist.org/; Koehn and Lintermans 2012).

Ensuring that Australia's most important food production area thrives while balancing the need to protect and restore freshwater biodiversity has been at the forefront of scientific and policy debates for decades (Goss 2003). The urgency of this debate has increased given that climate change is anticipated to put further pressure on already limited water resources (Wei et al. 2011). The Murray–Darling Basin Plan (https://www.mdba.gov.au/basin-plan/plan-murray-darling-basin) was developed in an attempt to bring the basin back to a healthier and sustainable state while continuing to support farming and other industries

for the benefit of the Australian community. The plan was developed collaboratively (including recognizing the rights of all riparian stakeholders) and launched in 2012. Much of the riparian area within the basin is privately owned, which necessitates partnerships between government and landowners (Jansen and Robertson 2001). The plan is basin wide, multifaceted, and considers the need to incorporate strategies that account for climate change (Hart 2016b). Protection and restoration of riparian habitats is just one of the strategies but is key for protecting water quality and supporting freshwater biodiversity in the river and riparian habitats, including floodplain wetlands (Ralph and Rogers 2011). A report that summarizes the state of riparian protections (e.g., policies regarding setbacks) emphasizes the complexity of the topic given multi-scalar governance and various planning instruments (Eco Logical Australia 2016). Riparian setbacks have yet to be standardized and fully implemented, being of secondary priority to developing and implementing water allocations, but key barriers to implementation have been identified (Hart 2016a). Water allocations were a priority for the early phases of the plan (Bark et al. 2014), so as those efforts progress it is anticipated that more attention will be devoted to riparian protections and restoration. This example of the Murray–Darling Basin plan illustrates the benefits of examining efforts at river, riparian, and floodplain protection and restoration, the various successes and failures of which can provide lessons that can be applied elsewhere (as per Hart 2016a).

CONCLUSION

Giving the stream more of its valley

What is proposed here is not novel (e.g., see the American Fisheries Association's Strategies for Stream Riparian Area Management; https://fisheries.org/policy-media/policy-statements/afs-policy-statement-14/), yet at the same time, we continue to fail to protect freshwater ecosystems and have not adopted proven strategies. Farm fields, industry, forestry, and housing developments around watercourses continue to be prioritized at the cost of the stream and its valley (Fig. 2). Much of the damage has been done over the last 50 y, and it is not too late to allow perturbed systems to naturalize, to engage in active restoration, and to protect remaining intact systems. Backing off is often sufficient to allow systems to re-naturalize (Feld et al. 2011, Birnie-Gauvin et al. 2018), but in some instances focused planting is needed (Richardson et al. 2007, Roni and Beechie 2013, González et al. 2015). Given that healthy riparian systems have the potential to address multiple stressors (Feld et al. 2018) and in many cases do not require massive capital investments, riparian protection is an example of low-hanging fruit when

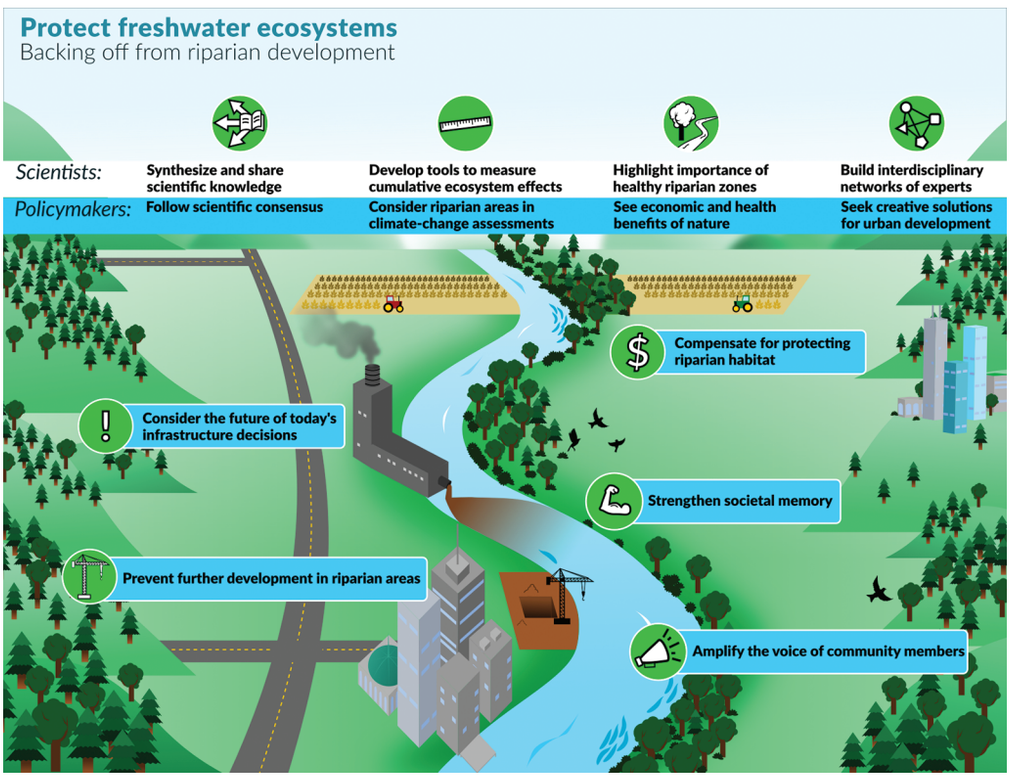

Figure 2. Conceptual diagram highlighting some of the ways in which scientists and policymakers can protect freshwater ecosystems by backing off from riparian development.

it comes to using nature-based solutions to address the freshwater biodiversity crisis. As we enter the United Nations Decade for Ecosystem Restoration (Cooke et al. 2019), it is timely to consider how we restore our degraded riparian areas and develop the courage to keep future developments back from surface freshwaters. Doing so will require cooperation of many actors—from planners to community members—and recognizing the inherent connections between freshwater ecosystems and people (Naiman 2013, Rieman et al. 2015). Such work cannot be done in a vacuum and will work best if incorporated into broader-scale catchment management efforts (ISAB 2011). What is clear is that it is time to back off from the stream and its valley and embrace the legacy of Noel Hynes.

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Positionality statement: This is a perspective article such that the ideas shared here are a culmination of our lived experiences and learnings. We acknowledge that we are all settlers in Canada and hold various positions ranging from trainees to tenured professors working in the academy. Our training is largely based on a Western science paradigm (largely in the natural sciences but with some complementary human dimensions training), and we acknowledge and value diverse knowledge holders and other ways of knowing and learning. We have worked around the globe, and those experiences have informed our perspective, but we do not pretend to communicate on behalf of any individuals or groups. As noted before, this is our perspective.

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