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The Essential Role of Wetland Restoration Practitioners in the Science-Policy-Practice Process

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We conducted a "living laboratory" study using a holistic transdisciplinary approach to demonstrate how new scientific tools and policy instruments could be mobilized to achieve wetland restoration goals. Our living laboratory was situated on the prairie pothole landscape in the province of Alberta, Canada, where policies require the replacement of lost wetland habitat. We created tools to map ditch-drained wetlands and to measure their functions in terms of hydrological health, water quality improvement, and ecological health to optimize targeting of wetland restoration sites. We also tested new policy instruments to incentivize private landowners to restore ditch-drained wetlands. However, we arguably failed in the implementation of the restoration program due to barriers that severely limited landowner participation, resulting in only a small number of wetlands being restored. Despite strength in science and a profound understanding of the policy, on-the-ground restoration work was stalled due to the interactive effects of environmental, social, economic, and political barriers. We discovered that despite our focus on overcoming the science-policy gap, it is the practice realm that requires more attention from both scientists and policy makers engaged in wetland restoration activities. Generally, the tools we developed were irrelevant because of complex interactions between actors and barriers within the policy, governance, and site-specific contexts that limited the use and application of the tools. Our living laboratory highlights the risks of engaging in use-inspired research without having a clear understanding of the actors and the interacting contexts that influence their behavior, motivations, and risk tolerance. Informed by our experiences, we offer key considerations for better engagement of practitioners in the design and implementation of wetland restoration programs.

Keywords: wetland, restoration, policy maker, scientist, practitioner, living laboratory, lessons

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INTRODUCTION

Wetlands are the most threatened ecosystem on the planet (Junk et al., 2013; Davidson, 2014). Yet wetlands are an essential component of water resource management (Cohen et al., 2016). Wetlands are a keystone ecosystem for a large number of terrestrial and aquatic species (e.g., Zamberletti et al., 2018; Zaffaroni et al., 2019), as well as being significant components of larger hydrological

(Rains et al., 2016) and biogeochemical (Marton et al., 2015) systems. The current state of knowledge about the importance of wetlands and their losses communicates an urgent need for better policy to protect remaining wetlands and their ecosystem functions and associated services (Costanza et al., 1997; Cohen et al., 2016), and for better management tools to restore drained or degraded wetlands in landscapes where losses have been especially acute (Dahl and Watmough, 2007; Clare and Creed, 2014).

Wetland management strategies have come under increased scrutiny and criticism (Creed et al., 2017; Golden et al., 2017), and a more holistic, systems approach is needed to achieve better outcomes (Peterson, 2000; Nightingale, 2003; Nygren and Rikoon, 2008). Despite this, studies examining wetland management challenges are typically focused within a single science, policy, or practice realm, with little consideration for how these realms interact (Pritchard and Sanderson, 2002; West et al., 2019). These constrained views have often led to the development of wetland policy and supporting governance structures and systems that are sub-optimal, rigid, and slow to respond, ultimately resulting in the continued loss of socio-ecological resilience (Peterson, 2000; Holling, 2001; Gunderson and Holling, 2002).

Wetland management includes a vast array of actors and interests that operate and change across temporal and spatial scales, making wetland restoration a challenging task. The convergence of different perspectives, approaches, and tools from diverse disciplines is essential to success but is difficult to achieve, due in part to epistemological differences as well as frequent difficulties in effective communication across disciplines and cultures for academics, policy makers, and practitioners. Despite this, there are increasing calls for evidence-based policy and for academic scientists to be included in environmental planning and policy making (Bruce and O'Callaghan, 2016; Gual Soler et al., 2017; Cvitanovic et al., 2018). Ultimately, learning from experience and sharing the most salient lessons—both the successes and the failures—are critical for the advancement of both science and policy research agendas.

WETLAND RESTORATION: THE CONTEXTS AND ACTORS

We present a framework where we show how actors who play a role in wetland restoration—both individuals and collectives (organizations or groups)—are influenced by a range of contextual factors (**Figure 1**; Bressers, 2009; Bressers and de Boer, 2013). In our framework, there are three key characteristics of actors: information they hold to be true; the motivations that drive their actions; and available resources that give them power and allow them to act (Bressers and de Boer, 2013). The actors are influenced by the wider policy context (e.g., the political system; economic drivers; social and cultural values; and available technology), the structural context (e.g., land rights; governance systems including jurisdictions; actors and their networks; perception of the problem; ambitions; strategies; instruments; and resources and responsibilities for implementation), and the site-specific context (e.g., the place; past decisions; specific circumstances) (Bressers and de Boer, 2013). Using this framework, we describe how actors and their interactions can influence wetland restoration outcomes. Our assumption was that wetland restoration outcomes would be a function of the strength of the science, policy, and practice; a deficiency in any one of these realms would lead to a deficiency in the wetland restoration outcome (**Figure 1**). Thus, actors within each realm must understand the contextual factors that motivate decisions to achieve desired wetland restoration outcomes.

In our conception of how actors involved in wetland restoration interact, the actors can generally be organized into one of three realms: science, policy, and practice.

Actors within the policy realm include those who are responsible for broadly developing wetland management strategies. Policy actors are responsible for developing the "high-level" vision for policy and management, with consideration of how new policy generally aligns with other existing policy and legislation. Policy actors include individuals from multiple jurisdictions across a range of scales, including municipal, state/provincial, federal, and indigenous governments. Policy actors also include a wide range of stakeholders representing different private and public interests.

Actors within the science realm include scientists whose primary focus is research. Generally, calls to close the science-policy-practice gaps are directed toward academic scientists within this realm to focus on research that will inform the development of policy, or that will develop knowledge that can be used to improve policy implementation or measure progress toward achieving policy goals. But increasingly, there are calls for actors within the science realm to move from addressing general principles to answering practical application questions that can inform practice (Ruhl et al., 2021).

The final set of actors are diverse and are typically located within the practice realm. It is within this realm that the on-the-ground implementation of policy occurs and, in this context, the transfer and translation of scientific tools to achieve desired policy outcomes (Owens and Bressers, 2013). The make-up of actors within the practice realm can vary depending upon the site-specific context of each wetland restoration project, but for most projects there are three primary actors in this realm: the regulator, the restoration agent, and the landowner.

The regulator includes government personnel from multiple jurisdictions and agencies. These actors typically include front-line bureaucrats who are responsible for interpreting broad, ambiguous, and sometimes conflicting laws or policies across multiple layers of implementation (Lipsky, 1980; Coslovsky et al., 2011). The types of decisions being made by regulators are complex, time sensitive, and are being made in environments where personnel often feel under-resourced (Mitnick, 2011; Clare and Krogman, 2013). This can lead to decisions that deviate from, or even contradict, the originally stated goals of the agency (Freudenburg and Gramling, 1994; Krogman, 1999; Coslovsky et al., 2011; Clare and Krogman, 2013).

The regulator frequently interacts with the wetland restoration agent, who is responsible for interpreting and applying government guidance documents related to wetland assessment,

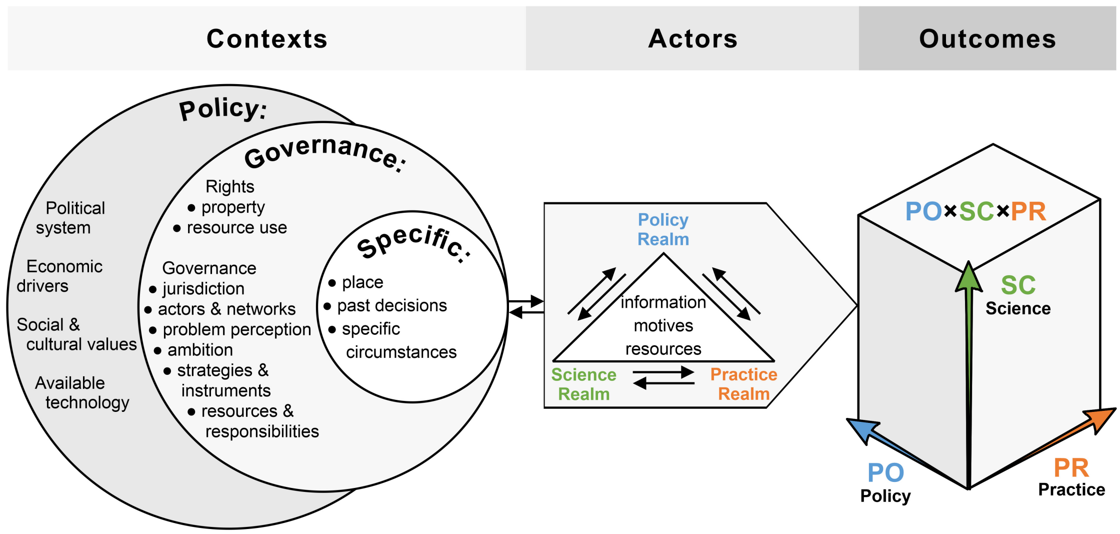

FIGURE 1 | The multiple contexts that influence the decisions and actions of wetland restoration actors and the interaction of knowledge and action among the policy, science, and practice realms in the production of wetland restoration outcomes (modified after Bressers, 2009). A positive wetland restoration outcome is contingent upon the strength of actions and decisions within each of the science, policy, and practice realms.

monitoring, and restoration. The role of the wetland restoration agent in the practice realm is complex, and these actors often include environmental consultants but can also include a wide range of other private and not-for-profit agencies. The restoration agent must have expertise in wetland science while also having extensive knowledge of the complex (and often contradictory) web of policies and regulations that govern their decisions and practices. Their work is often diverse and may include any number of tasks including: site planning and assessment; regulatory permitting; and designing, executing, and monitoring wetland restoration plans. These tasks are often done under extreme (some may say, unrealistic) time pressures, all while they are being called upon to integrate the "best" and most current science into their daily practices, even in circumstances where the use of such knowledge may conflict with existing regulatory or policy guidance and/or requirements.

In many wetland restoration projects, regulators and wetland restoration agents engage directly with landowners. Eligible wetlands are frequently located on private lands, thereby requiring negotiation with and recruitment of landowners into the wetland restoration program. Landowners often include agricultural producers with little or no knowledge of wetland management or restoration policies, regulations, or practices, and who are members of communities where there is a strong culture of wetland drainage.

THE ALBERTA LIVING LABORATORY PROJECT

We illustrate the importance of understanding the multiple contexts and actors (**Figure 1**) for use-inspired wetland restoration activities by describing our experience working on a living laboratory project in the province of Alberta, Canada. Living laboratories are defined as "physical regions or virtual realities, or interaction spaces, in which stakeholders form public-private-people partnerships (4Ps) of companies, public agencies, universities, users, and other stakeholders, all collaborating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts" (Westerlund and Leminen, 2011; Leminen, 2013). More concisely, living laboratories are "used by communities ... for innovation" (Leminen, 2015).

Policy Context

The contemporary management of wetlands in Alberta has been largely informed by a resource-centered paradigm that has dominated the social and political culture of the province since settlement began in the late 1800s. From the earliest days of the agrarian settlement of the province, common law and statutes were designed to maximize agricultural production by granting secure access rights for water withdrawal or diversions, easily allowing for wetland drainage. As a result, Alberta—and more generally the Prairie Pothole Region of North America—has lost wetlands at a remarkable rate (Government of Alberta, 2013). The majority of wetland loss in the Prairie Pothole Region can be attributed to drainage for agricultural and urban development (Clare and Creed, 2014; Davidson, 2014). In particular, agricultural producers drain or alter wetlands to increase cultivated area as well as to increase within-field operational efficiency (Van der Gulik et al., 2000; Blann et al., 2009; Clare et al., 2021).

Governance Context

Within Canada, Alberta was one of the first provincial jurisdictions to introduce a provincial wetland policy. This policy focused on the management of freshwater mineral wetlands in the settled region (or "White Area") of the province. The implementation of the policy focused on achieving a "no net loss" of wetland area through the application of the mitigation hierarchy, which first aimed to avoid loss of wetlands, then to mitigate for the loss or degradation of unavoidable impacts as near to the site of impact as possible, and finally to enhance, restore, or create wetlands in areas where these had been depleted or degraded (Alberta Water Resources Commission, 1993). While the policy was adopted in 1993, it wasn't until 1999 that the government introduced the *Water Act*, which created a legislative requirement to obtain a permit to conduct activities that negatively impact wetlands. Despite having both policy and laws that promote wetland avoidance, there has been a continual decline in the number and quality of wetlands in Alberta (Clare et al., 2011; Clare and Creed, 2014).

In response to this failure, the Government of Alberta released a new wetland policy in September 2013 that applies to all lands throughout the province. Notably, while this new wetland policy was released in 2013, its implementation has been phased in over a period of more than 5 years. Within the White Area, the policy did not come into effect until June 2015, with implementation in the more northerly and less settled "Green Area" of the province occurring in June 2016 (Government of Alberta, 2015a). In practice, this meant that any permits issued between September 2013 and June 2015 (in the White Area) or June 2016 (in the Green Area) were not subject to wetland replacement requirements specified in the 2013 wetland policy (Government of Alberta, 2015a). This phased implementation has created a great deal of uncertainty, confusion, and frustration for regulators as well as for those applying for wetland permits.

One of the most notable changes between the 1993 and 2013 wetland policies is the inclusion of wetland functions in the evaluation of a wetland's replacement value (Government of Alberta, 2013). In this context, a wetland's value is represented by a unitless A-B-C-D score that is evaluated using five wetland function criteria (**Table 1**). Several of the wetland function criteria have sub-functions that contribute to a wetland's overall value score (Government of Alberta, 2013, 2015b; **Figure 2**). Wetland replacement ratios are based on the value score of the lost wetland relative to the value of other wetlands located within a defined relative wetland value assessment unit (RWVAU; Government of Alberta, 2018). For any wetland that is permanently reduced in area, the wetland must be replaced through permittee-responsible restoration or construction of a new wetland, or through the payment of a wetland replacement fee (i.e., in-lieu fee payment). Wetland replacement ratios range between 0.125:1 and 8:1 for permittee-responsible replacement and between 1:1 and 8:1 for projects utilizing a replacement fee (**Table 2**). Within each RWVAU, the goal is to achieve an average replacement ratio of 3:1.

TABLE 1 | Wetland value criteria used to estimate wetland value categories.

Wetland function and value criteria		Wetland value categories
Ecological health	→	High (A)
Water quality improvement		Moderate (B)
Hydrological function		Moderately Low (C)
Human uses		Low (D)
Abundance		

The value categories are used to determine the replacement value of a wetland that is permanently lost as a result of reduction or removal of wetland area (Government of Alberta, 2013).

In order to derive a value score for both lost and replacement wetlands, the provincial government simultaneously commissioned the development of two standardized evaluation tools: a planning tool that estimates the relative value of wetlands using geospatial indicators (the Alberta Wetland Relative Value Evaluation Tool-Estimator or ABWRET-E), and an implementation tool that combines a number of geospatial indicators with observations from the field to derive a wetland value score (the Alberta Wetland Relative Value Evaluation Tool-Actual or ABWRET-A). ABWRET-E was developed as a tool that could be used at the project planning stage to promote avoidance of wetland loss or degradation. Further, ABWRET-E was envisioned as a tool that could be used to derive a value estimate for restorable wetland basins, thereby allowing for the targeting of limited resources toward wetlands that, once restored, offered the greatest hydrological, water quality improvement, and ecological benefits to surrounding communities.

Having tools that allow for the identification of wetlands that qualify for restoration is important for achieving wetland policy goals in Alberta. Creating information that allows for the prioritization of the highest value restorable wetlands ostensibly means that resources can be strategically targeted to achieve the best possible hydrological, water quality improvement, and ecological outcomes. Nevertheless, because most drained basins are located on private lands, having landowners who are willing to restore wetlands is essential to policy success.

Site-Specific Context

Given the apparent need to develop knowledge that can be used to improve wetland policy implementation and, specifically, wetland restoration outcomes, the Alberta Living Laboratory Project was launched in 2014 by a transdisciplinary team led by university researchers. This project focused on the needs of the City of Calgary (hereafter, the City), which had a specific wetland restoration problem. As one of only three agencies recognized by the provincial government as a wetland restoration agent, the City had amassed a large wetland compensation fund with an associated obligation to restore wetlands but had identified very few wetland restoration opportunities available to discharge this obligation. Further, there were competing regional water licensing and management issues that restricted how municipal surface water could be used to supply retained, restored, and constructed wetlands within the municipality. Given the shortage of restorable wetland basins within the City's boundaries, we focused on restoring wetlands within one of the watersheds that drains into the City: the Nose Creek watershed (**Figure 3**). While this watershed includes only a small portion of the City, it was selected because the watershed is located upstream of the municipality; thus, many of the ecosystem services associated with wetland restoration would still flow to end users in the City.

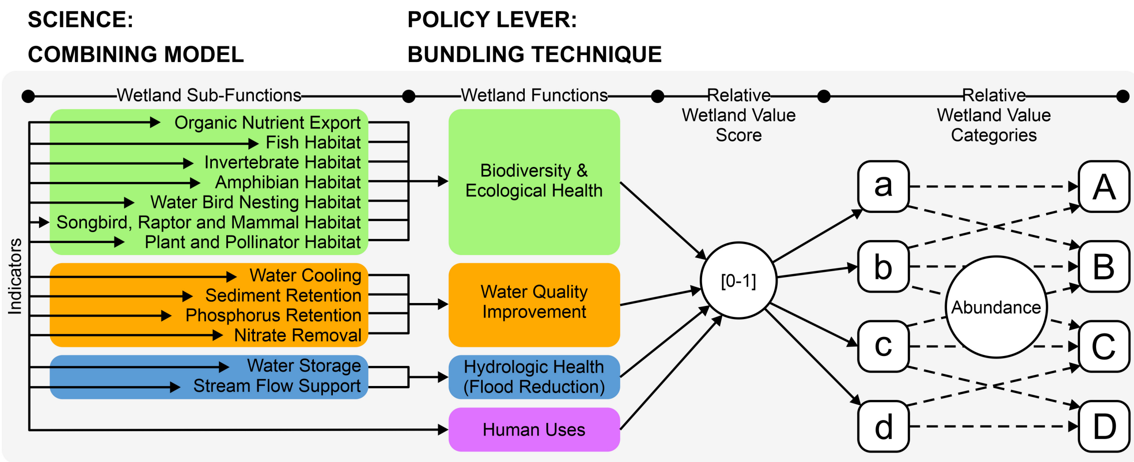

FIGURE 2 | Flowchart of Government of Alberta's (2013) wetland policy. ABWRET-E and -A tools use scientific knowledge and data to combine indicators of wetland sub-functions into wetland function scores that are then combined into (1) four wetland value functional groups and (2) value scores that are scaled to the range of wetland value scores within each RWVAU (relative wetland value unit). Government of Alberta policy levers are used (1) to classify relative wetland value scores into unitless a-b-c-d categories in descending order of relative value, and (2) to modify relative wetland value categories upward or downward based on the abundance (i.e., historical loss or gain) of wetlands within each RWVAU.

The Alberta Living Laboratory Project included actors within the science, policy, and practice realms (**Table 3**) with the objective to generate science and policy tools that would improve wetland restoration outcomes in Alberta.

The actors in the science realm included researchers representing a convergence of disciplines—environment, social, and economic—with a strong understanding of municipal and provincial wetland policy. The science team focused on developing practical methods for inventorying intact and ditch-drained (restorable) wetlands (Waz and Creed, 2017) and for predicting hydrologic health, water quality improvement, and ecological health scores for restorable basins (Creed et al., 2018), such that these scores could be used by the research team to locate and prioritize high value wetlands for restoration. In total, 20,027 intact wetlands covering 12,500 ha were identified in the Nose Creek watershed, with a total of 1,587 wetlands covering 1,220 ha being identified as ditch-drained (Waz and Creed, 2017; **Figure 3A**). For each wetland in the intact and ditch-drained wetland inventories, a relative wetland value score was estimated using 73 indicators extracted using GIS methods and existing geospatial data, and a wetland value category was assigned (**Table 1**). Wetland value categories were not distributed evenly throughout the watershed; higher value wetlands were located within natural areas at the outer margins of the watershed, while lower value wetlands were found primarily within the urbanized and agriculturally intensive central areas of the watershed (**Figure 3B**). Notably, ditch-drained (restorable) wetlands represented an opportunity to increase the cumulative value of wetlands in the watershed, with higher average hydrological health and water quality improvement function scores than intact wetlands (**Figure 4**).

TABLE 2 | Alberta wetland replacement matrix specifying the required replacement ratios for lost wetlands.

		Value of replacement wetland			
		D	C	B	A
Value of lost wetland	A	8:1	4:1	2:1	1:1
	B	4:1	2:1	1:1	0.5:1
	C	2:1	1:1	0.5:1	0.25:1
	D	1:1	0.5:1	0.25:1	0.125:1

The gray column includes the replacement ratios used to determine in-lieu fee payment amounts (Government of Alberta, 2018).

The science team also focused on designing and implementing a reverse auction (also known as a conservation tender) as a policy instrument to incentivize wetland restoration on private land (**Figure 5**). A reverse auction is a tender mechanism that is used to contract landowners to provide a public environmental good and includes a single buyer and many sellers who compete for a limited budget (Rolfe et al., 2018). Landowners submit bids to the buyer based upon a cost per environmental outcome and the bids are ranked according to the price per unit of environmental benefit (Hill et al., 2011). In our living laboratory, a conservation auction was chosen over a fixed payment scheme because some studies have shown that these tender mechanisms lead to efficiencies that increase the environmental benefit per dollar spent (McAfee and McMillan, 1987; Stoneham et al., 2003). This instrument offered an additional advantage of providing our team with insights into price discovery—in other words, the auction provided information on what landowners in the watershed were willing to accept as payment for restoring drained wetland basins. As part of the design and delivery of the reverse auction, our team also explored landowner attitudes and perceptions related to various design options for the auction (Kauffman, 2018) as well as attitudes and social norms related to wetland drainage (Cyr, 2016).

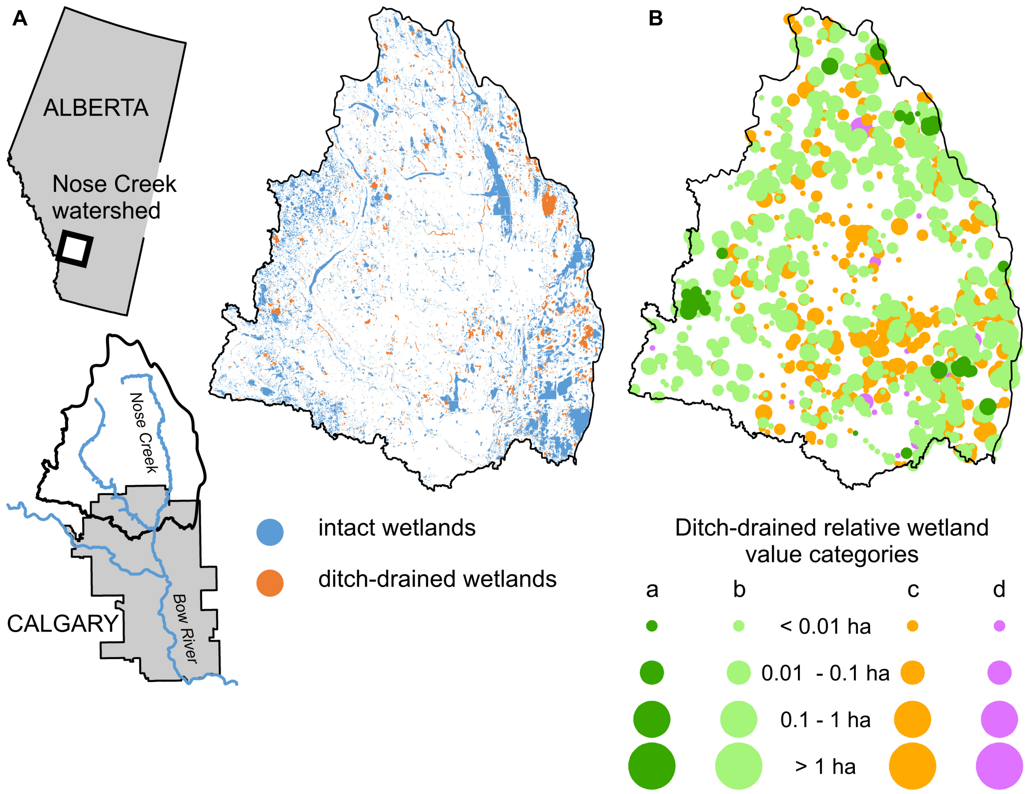

FIGURE 3 | (A) Intact and ditch-drained wetlands in the Nose Creek watershed. A total of 20,027 intact wetlands with a total area of 12,500 ha cover 14.1% of the watershed with a median size = 801 m^2 and an average size = 6,241 m^2. A total of 1,587 ditch-drained wetlands with a total area of 1,220 ha cover 1.4% of the watershed with a median size = 790 m^2 and an average size = 7,690 m^2. **(B)** Locations and sizes of in ditch-drained wetlands in the Nose Creek watershed per relative wetland value category.

Within the policy realm, the actors included members from the provincial government, including: program support from the Government of Alberta's Watershed Resiliency and Restoration Program, which aims to increase natural resiliency to flood and drought by restoring wetland and riparian habitats; and advisors from the Government of Alberta's Water Policy Branch, including mid-level bureaucrats involved in the development of directives and guidelines for the implementation of the provincial wetland policy.

Within the practice realm, the actors were diverse and included the City, the municipality of Rocky View County (in which the majority of Nose Creek watershed is located), landowners within the Nose Creek watershed, provincial government regulators, and a wetland restoration agent (Ducks Unlimited Canada; DUC) that carried out the restoration work.

Although we had a strong research team, and support from actors within the policy realm, our ambition to improve wetland restoration outcomes in Alberta by creating and applying new science and policy tools arguably failed. Despite having a restorable wetland inventory, prioritization tools for targeting high value restorable wetlands, a robust communication strategy that utilized a range of media and included well-constructed and diverse messaging, and a novel policy instrument that allowed landowners to specify the price that they were willing to accept as a payment for wetland restoration, we were only able to recruit four landowners over a period of 3 years. While participation rates in conservation auctions tend to be low (Rolfe et al., 2018), the small number of landowners who opted to participate in our auction was disappointing. Further, because of the small number of restorable wetlands that were enrolled in the project, the prioritization tools that we developed were not utilized to rank the winning bids in the conservation auction, and only 19 ha of wetlands were ultimately restored.

DISCUSSION

Important lessons can be learned from the failure of our living laboratory project. Many of the barriers that frustrated progress were not within the science or policy realm, but rather, included structures, processes, and actors within the practice realm. Below we discuss five of the most substantial barriers to progress that our team faced during the project.

Fractious Relationships

Our municipal partners included the City, a large urban municipality with over a million residents, and Rocky View

TABLE 3 | Actors within the science, policy, and practice realms involved in the living laboratory project.

Realm	Actor	Role/responsibility
Science	Project team Graduate students	• Developed tools to estimate regional wetland loss, map location and area of ditch-drained wetlands, assess wetland functions and relative wetland value in intact and drained wetlands, and monitor functions in restored wetlands. • Designed and implemented a reverse auction, including communications strategies for advertising the auction and recruiting landowners. • Coordinated permits and regulatory requirements for restoration. • Liaised with actors across all realms to facilitate discussions in an effort to resolve issues that prevented project progress.
Policy	Provincial government policy analysts	• Provided data sharing agreements and project funding • Provided advice on navigating regulatory issues.
Practice	Provincial government regulators	• Provided provincial permits to enable wetland restoration delivery agent to execute the work.[a]
	The City of Calgary	• Ensured project activities were consistent with municipal policy, direction given by the municipal Council, and legal requirements for utilizing the wetland compensation funds. • Helped navigate inter-municipal issues and relationships.
	Rocky View County	• Assisted with creation and implementation of the communication strategy. • Participated in and facilitated community engagement events, and engaged directly with landowners with eligible wetlands to encourage participation in program.
	Landowners	• Participated in communication and outreach campaign. • Recruited to restore wetlands.
	Ducks Unlimited Canada	• Served as delivery agent for the "on-the-ground" wetland restoration work once landowners were recruited, which included securing wetland restoration permits from provincial government, executing contracts with landowners who agreed to restore wetlands, conducting surveys of drained basins, installing ditch plugs, and monitoring restoration outcomes.

[a]*Generally, our interactions with front-line regulators were restricted to the formal wetland restoration permitting process, with discussions focused on what we could and could not do within the existing regulatory framework.*

County, a predominantly rural neighboring municipal district with less than 50,000 residents. As is the case with many neighboring municipalities, particularly where one is a large and rapidly expanding urban center, political disputes between the City and the County over land use and land management were prevalent. This history of conflict was a constant undercurrent to discussions and negotiations between the municipalities and between each municipality and the academic team. Further, the idea that rural landowners should restore wetlands to help an urban municipality meet their wetland compensation requirements was not popular and was viewed as unfair by many of the rural landowners.

Lack of a Functioning Restoration Economy

At the time, there were few agencies or organizations in Alberta with expertise in wetland restoration, and this lack of a functional restoration economy left our team with limited options for on-the-ground delivery of restoration projects. While our team had planned to help to facilitate the creation of a larger restoration economy by working with new organizations in the delivery of wetland restoration, we were limited in our ability to do so. This is because the provincial government ultimately required that DUC carry out all on-the-ground wetland restoration activities as it was the only organization that was authorized by the government to complete this type of work at the time.

This structural barrier imposed by the provincial government ultimately led to issues of trust with landowners in our study area. While many landowners support the restoration work that is done by DUC, there are others who do not trust the organization, and the requirement to work directly with DUC was a barrier to participation for some landowners (Kauffman, 2018). This structural barrier also led to tensions between the City, who was the wetland restoration agent engaged to fund the restoration work and bank the wetland restoration credits, and DUC, who was the wetland delivery agent for this project. DUC typically acts as a wetland restoration agent in its own right and, because of its own organizational mandate and commitments, was initially reluctant to participate in this project. This reluctance was tied to a number of factors, foremost of which were capacity issues. As a wetland restoration agent, DUC had its own existing habitat replacement obligation, and a limited number of personnel available to execute restoration work on the ground. In many ways, the government's requirement that the City work with DUC to restore wetlands created competition between these two wetland restoration agents, which caused tension and slowed progress, and ultimately created barriers to achieving wetland restoration.

Control and Ownership of Land

Obtaining consent from landowners to restore a wetland was logistically challenging and presented a barrier to landowner recruitment. Wetland inventories are essential planning tools for identifying restorable basins, and the scientific tools that are available to create such inventories are becoming increasingly more sophisticated and accessible. What is *eligible* for restoration, however, is not the same as what is *accessible* for restoration, particularly when dealing with restorable basins that are located on private land. We observed several barriers to landowner participation. In some cases, these barriers were intrinsic (e.g., attitudes and beliefs about wetland restoration, see Cyr, 2016; Kauffman, 2018). In other cases, formal and informal control over the lands on which the wetlands were situated was a barrier. For example, many of the landowners who had eligible wetlands did not have complete control over decisions related to how their lands should be managed because they rented their lands to other producers.

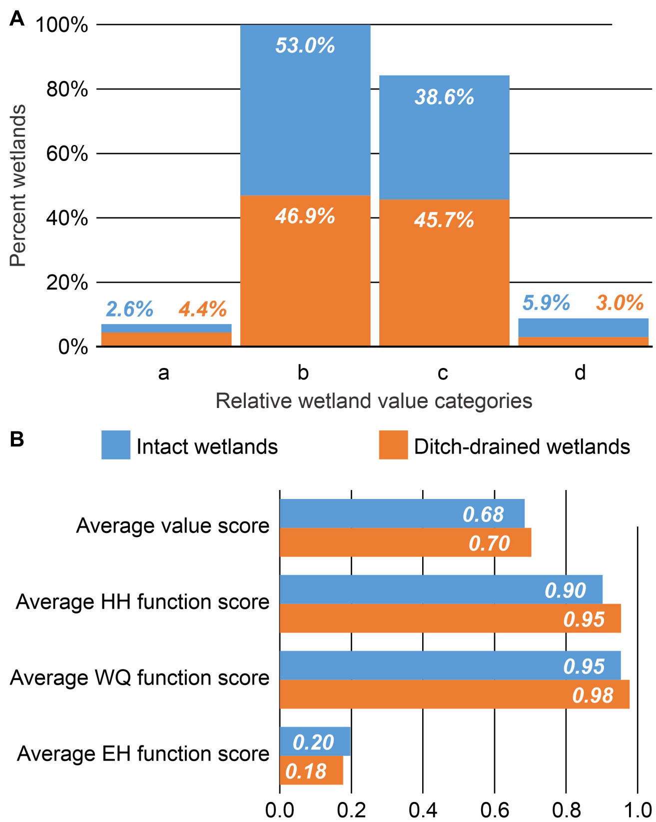

FIGURE 4 | **(A)** Distribution of intact and ditch-drained relative wetland value categories in the Nose Creek sub-watershed. **(B)** Average value and function scores in intact and ditch-drained wetlands. Human use functions were not assessed within our project.

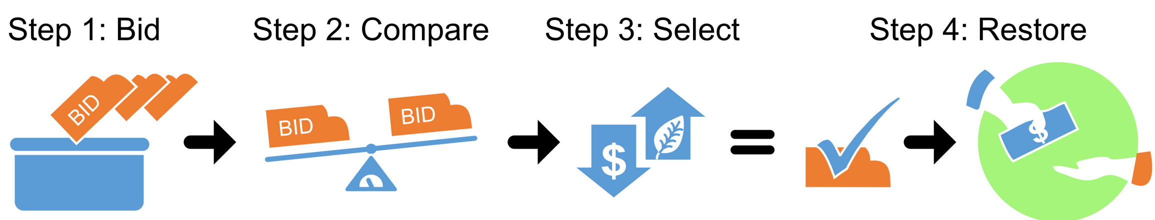

FIGURE 5 | We tested a conservation auction as a mechanism to incentivize wetland restoration on private land as part of the Living Laboratory Project.

We had several cases where absentee landowners were interested in participating in the reverse auction, but were leery of making land management decisions that would have a direct impact on the producers renting their land, or that would impact the desirability of the land for potential renters. This experience was consistent with other studies that have also reported that producers living on-farm are more likely to participate in conservation or restoration programs than those who lived off-farm (Stroman et al., 2017; Wachenheim et al., 2018). Consequently, recruiting participants into a wetland restoration program in an area where a large proportion of land is being rented or leased may be more challenging than in areas where the majority of farms are owner-operated.

Additionally, we had a large number of eligible wetlands that were "shared" amongst multiple family members or business partners, or spanned property boundaries such that the wetland was not confined to land that was under the control of a single landowner. In more than one instance, we had a landowner with a "shared" wetland who was interested in participating in the reverse auction but neither the landowner nor our team were able to persuade their family member or their neighbor to also participate. Convincing multiple landowners to participate in a wetland restoration project is not impossible but it does require a substantial increase in time and resources. This is particularly true in agricultural landscapes, where enthusiasm for wetland restoration is typically low (Rispoli and Hambler, 1999), and convincing more than one producer or family member of the benefits of wetland restoration while contending with complicated social dynamics among the parties becomes a disincentive. As a result, focusing attention on restoring "shared" basins may not be practical, despite the fact that these basins may offer substantial hydrological, biogeochemical, and ecological benefits or improvements.

Recalcitrance About Change and Aversion to Risks

Throughout the project, it was very apparent that we were working within a regulatory regime and associated processes that were designed to issue wetland drainage and loss permits. As a result, it was much easier and faster to obtain a permit for wetland drainage than it was to secure a permit for wetland restoration.

At the outset, the living laboratory team saw the project as an opportunity to test implementation tools that could ultimately improve policy outcomes. To do this, however, our team needed regulatory leeway, which required regulators to accept and approve requests that were not the "typical" way of doing things. Ultimately, the regulators were reluctant to allow for such deviations. This included modifying contract conditions with landowners to improve restoration uptake or working with restoration delivery agents other than DUC. In some cases, these regulatory barriers slowed decision-making processes, and in other cases, they prevented creative solutions and caused friction with those engaged with on-the-ground wetland restoration activities.

Much of the reluctance to test new ideas and approaches may have been due to the timing of our project—we were executing this research at a time when new wetland policy directives were actively being developed. Consequently, our team was often uncertain about what the "rules" were, and this was because they were actively being written while we were conducting our living laboratory project. Few of the front-line decision makers we encountered were comfortable approving restoration work that did not conform with existing (or future) government directives. Reluctance by government regulators to step outside the bounds of what is "acceptable" is often related to concerns over reputational risk, with public servants adopting a more cautious position on decisions that may cause damage their reputation (Rickards et al., 2014; Alexandra, 2021). In particular, in instances where there may be scientific or policy uncertainty, adhering to established practices and procedures is a much "safer" approach and reduces personal risk to individual decision makers (Cleaver and Franks, 2008).

Ambiguous Goals and Conflicting Demands

Our study occurred within a watershed with highly politicized water use and licensing issues, and these issues ultimately competed against our efforts to restore wetlands. These issues created uncertainties around which wetlands were eligible for restoration and what information and studies were required to support an application to obtain a regulatory permit for restoration. These uncertainties resulted in protracted discussions with regulators that significantly slowed progress, and in at least one case resulted in a landowner dropping out of the restoration program.

There was also ambiguity related to whether the regulatory priority was restoring wetlands to meet provincial policy goals or taking enforcement action against landowners that we were actively trying to recruit into our program. From the outset, the provincial government made it clear that only wetlands with a clearly visible drainage ditch would be eligible for restoration; however, mid-way through our project we were told that any drainage ditch that had been created *after* 1999 (when the *Water Act* came into force) that did not have an existing permit authorizing the drainage would be considered illegal and the landowner would be charged by the enforcement agency. This position by the regulator did little to create trust between our team and the landowners. It also severely frustrated our landowner recruitment efforts by creating a substantial barrier that significantly reduced the number of legal options available for wetland restoration.

RECOMMENDATION: BETTER ATTEND TO THE NEEDS OF WETLAND PRACTITIONERS

We found significant weaknesses in the science-policy-practice system of decision-making related to wetland restoration. In particular, we found a significant lack of coherence at the interface between the practice realm and the science and policy realms—the space where newly generated ideas and knowledge is taken up and used or implemented by practitioners. This highlights the need for those who work within the science and policy realms to be more attentive to the needs of, and pressures felt by, wetland restoration practitioners, because even when the "best" science or policy is produced, it may be insufficient to overcome the barriers that exist in their implementation. Because of this, those who engage in use-inspired research must acknowledge at the outset that the science-policy-practice system is a highly politicized assemblage of actors that are all motivated by a wide range of contexts that can profoundly influence decisions and outcomes (**Figure 1**).

Too often, science and policy actors assume that new knowledge can be simply "transferred" into the practice realm and put into action in ways that result in meaningful benefits (West et al., 2019; Alexandra, 2021). This assumes that knowledge and action exist within separate domains and that knowledge simply needs to be "linked to action" to be effective (Bruce and O'Callaghan, 2016; Rose et al., 2019; Fisher et al., 2020; Alexandra, 2021). Our living laboratory project illustrates the complexities associated with introducing new information and tools into existing decision-making processes. Whether new science and policy tools are adopted for use by practitioners has little to do with how "good" they are (De Boer and Bressers, 2011).

Based upon our experience, we implore those who are engaged in use-inspired wetland restoration activities to be more attentive to the needs of practitioners. To do this, myriad factors must be considered, including the wider policy, governance, and site-specific contexts for how practitioners conduct their work, the practical constraints that limit their ability to utilize the information and tools, and their motivations for doing so. To assist with this, we provide several questions that should be considered before engaging in activities that aim to develop new science or policy tools that are destined to be utilized by wetland restoration practitioners (**Table 4**). While this list of questions is not exhaustive and may include questions that may not be relevant in some circumstances, it serves to highlight the wide range of factors that may influence the motivations and interactions of actors involved in wetland restoration programs.

Notably, our experience conducting use-inspired research uncovered several serious barriers that limited the number of wetlands that were ultimately restored as part of our restoration program. Because our team included wetland restoration practitioners, many of the barriers we encountered were identified at the outset as issues that we needed to actively manage. For some of these barriers, such as land ownership, we had limited control over solutions to the problem. For other barriers, such as the fractious relationships between project partners and the reluctance of regulators to make "risky" decisions, we underestimated the level of impact that these factors would have on outcomes. This highlights how inherently political wetland management is in Alberta.

Ideally, we would offer a range of potential solutions to the barriers we faced or provide a list of suggestions for how others can avoid the same pitfalls that we encountered. We can offer no such list. With time, we feel that some of these barriers could have been overcome through trust and relationship building with wetland restoration practitioners, but we cannot definitively say that this would have improved outcomes. Further, we searched the literature to find specific suggestions for how to address implementation challenges such as the ones we faced, and beyond general recommendations that cite a need to "better engage" and "co-create knowledge," we can offer no specific recommendations, which highlights an urgent need. Because of this, we join other scholars (e.g., Cvitanovic et al., 2018; Rose et al., 2019) in calling for more research that puts an emphasis on overcoming implementation challenges, not simply identifying information and tools for assisting with implementation. Indeed, researchers need to not only identify and acknowledge implementation barriers, they also need to integrate efforts to overcome these barriers into their research agendas. Notably, not all implementation barriers may be overcome. Some barriers may be intractable, and the potential solution for other barriers may not be practical given existing time and financial resources. In these cases, simply highlighting the existence of the implementation barrier may be sufficient to allow for better policy design and more transparent evaluation of policy outcomes. Ideally, these new research agendas will include the participation of actors from all three realms—science, policy, and practice—and will create tangible examples of how wetland restoration implementation barriers can be effectively addressed and overcome.

TABLE 4 | Questions that should be considered by science and policy actors prior to engaging in use-inspired research to ensure the needs or practitioners are considered in the design and implementation of wetland restoration programs.

Wider policy context	Governance context	Site-specific context
What are the competing economic interests?	What competing policies or legislation may create goal ambiguity?	What is the background and experience of the regulator and/or science practitioner(s)?
How receptive are private landowners and the wider community to wetland restoration?	What is the risk tolerance of the regulatory agency/agencies?	What regulatory decision-making precedents are there?
What tools and information are available to inform restoration design and monitoring decisions and practices?	What are the routine decision-making practices that may influence outcomes?	What authority do regulators have to deviate from "the rules"?
	Where does wetland restoration fit within the list of other regulatory priorities?	How much discretion does the regulator have within their office/agency?
	What are the regulatory requirements for assessment and monitoring?	What are the time and budget pressures/constraints associated with the restoration work?
	How much regulatory leeway is there to integrate new scientific information into restoration practices?	What types of wetland restoration sites are available?
	Is a permit required for restoration?	Are there specific regulatory criteria for restoration eligibility?
	How difficult/time consuming is obtaining a permit?	How willing are private landowners to engage in wetland restoration?
	Are there standards for conducting restoration?	What is the process for wetland securement?
	What is the risk of restoration failure?	Who is paying for the restoration?
	What are the challenges associated with securing a permit for restoration?	Where is the restoration site located and what are the site-specific constraints?

CONCLUSION

All relevant actors in each of the three realms of decision-making (science, policy, practice) need to be involved in both the wetland policy development and the decisions and actions that inform policy implementation. Our experiences working on this living laboratory project clearly illustrate that developing better policies or scientific tools to implement these policies is insufficient to advancing wetland restoration outcomes. In our living laboratory project, the scientific tools developed for targeting and prioritizing wetlands for restoration were irrelevant because many of the wetlands identified as good candidates for restoration were either not eligible or faced constraints from land ownership issues. Further, the resistance from regulatory agencies to issue permits for wetland restoration, tensions between municipal partners, tensions between municipal partners and the wetland restoration agent, and slow administrative decision-making processes, revealed the practical challenges of executing wetland restoration in the "real world." Engaging in use-inspired research without a clear understanding of the actors and the multiple contexts that influence the behavior, motivations, and risk tolerance of the actors will prevent the effectiveness of wetland restoration programs. To be effective, wetland restoration programs need to engage not only those who are able to make policy, and those who conduct science to help inform and implement policy, but also those front-line practitioners who are able to take meaningful action on the ground.

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SC and IC contributed their research, experiences, and perspectives gained from working on the Alberta Living Laboratory Project. Both authors contributed to the article and approved the submitted version.

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