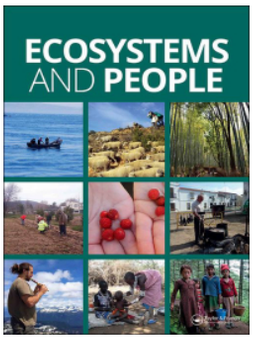

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Facing the challenges of using place-based social-ecological research to support ecosystem service governance at multiple scales

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ABSTRACT

Place-based social-ecological research is often designed to improve local environmental governance, but it can also inform decisions at larger scales or in other places. However, the focus on local perspectives in such research creates challenges for transferring insights to other locations, and for aggregating understanding to larger scales. In this paper, we discuss how ResNet, a new pan-Canadian network of researchers working on place-based social-ecological case studies via ecosystem services, will face (and hopefully overcome) these challenges while taking advantage of the unique benefits of a place-based approach. Drawing on insights from the literature and from the first 10 years of the Programme for Ecosystem Change and Society (PECS), we outline solutions to six key challenges to multi-scale knowledge integration across place-based cases, and explore how ResNet is employing some of these solutions.

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Introduction

Deteriorating planetary health demands urgent action at all scales, but the most prominent work so far has been too abstract to lead directly to pragmatic solutions, nor is there a clear organization with a mandate for global-scale environmental policy (Norstrom et al. In prep for this issue). Nevertheless, the science of global sustainability has advanced on several crucial fronts. These advances include developing a better understanding of how ecosystem services support human well-being (Millennium Ecosystem Assessment (MA) 2005; Díaz et al. 2019), exploring the role of human activities in climate change, and quantifying the deterioration of nature's contributions to people around the world (Díaz et al. 2020; Brauman et al. 2020). There remain, however, major gaps in sustainability science at the global scale. In particular, large-scale sustainability science suffers from a lack of cross-sectoral and cross-disciplinary integration (Lang et al. 2012; Stafford-Smith et al. 2017), difficulty incorporating traditional and other forms of local knowledge (Tengö et al. 2014; Lam et al. 2020), and sometimes, a failure to adopt key solutions, typically because mechanisms for engaging communities or incorporating information into decisions are absent or unclear (Wiek et al. 2012).

Placed-based social-ecological science is one way to use the urgency of research on planetary boundaries to drive solutions that engage local actors (Matson et al. 2016). The foundations of place-based social-ecological research are the linkages between social and ecological systems that can cause abrupt and nonlinear change, and the role of the specific location in setting the critical context for these linkages (Carpenter et al. 2012). The aim of this type of research is often to provide theory and tools for researchers as well as for policy- and other decision-makers in sustainability governance. Place-based research builds on a long tradition of local involvement often (but not exclusively) found in the humanities and social sciences that highly values the role of context. As such, it lends itself to achieving cross-disciplinary results by building trust among actors (Fischer et al. 2014), amplifying missing voices (Lam et al. 2020), potentially levelling long-standing power imbalances, and motivating action by individuals (Karrasch et al. 2017), hence filling some critical gaps in global sustainability science (Clark and Harley 2020).

For these reasons, placed-based social-ecological research has an important, and increasingly recognized, place in understanding and improving sustainability at local and regional levels. Place-based research can also

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trigger transformations to sustainability, integrating social and ecological information into decision-making by bringing researchers and decision-makers together across disciplines and sectors (Mooney 2016). Yet to address the grand challenges of sustainability, it is crucial that we anticipate how a variety of management actions will affect social-ecological systems in order to take more effective management action across many spatial and temporal scales (Levin 1992; Borer et al. 2014). Sustainability scientists are thus attempting to aggregate learning from placed-based social-ecological research by drawing general conclusions across many cases to develop understanding at the regional, national, or even global scale (Balvanera et al. 2017; Mirtl et al. 2018; Fischer et al. 2021).

We are confronted with two paradigms of research in the sustainability sciences. Larger-scale research that explores the broad trends and themes at work in our relationship with the entire biosphere, drawing on a long-standing intellectual tradition, sometimes referred to as *nomothetic research*, which seeks broad trends and describes generalizable phenomena. In contrast, local work draws on an *idiographic tradition* of scientific research that is rooted in the specifics of a particular context (e.g. Cooke et al. 2016). Clearly, both nomothetic and idiographic work are critical to understanding, and managing for, sustainability at multiple scales. Thus far, however, while results of large-scale nomothetic work are used to justify local action (e.g. using the outputs of global circulation models to justify local climate change mitigation strategies) place-based research only infrequently informs national or global science and policy (McGowan et al. 2014). For example, efforts to develop local scenarios have promoted dialogue, resolved conflicts, and led to learning among stakeholders, researchers, and policy makers, and have improved natural resource management (Oteros-Rozas et al. 2015); however, global scenario development rarely picks up on this richness (Balvanera et al. 2017). A critical and unresolved issue in social-ecological research is how widespread and pressing sustainability challenges can be better addressed by combining the best aspects of idiographic and nomothetic approaches. In this paper, we will focus on the role of place-based work in addressing widespread sustainability challenges.

The working landscapes that we focus on are all social-ecological systems, which are a type of complex adaptive system. This means that that these systems feature interacting heterogeneous agents making decisions where the aggregation of, and interaction among, actors can lead to emergent outcomes. These emergent properties of complex systems mean it is impossible to simply "scale up' placed-based case studies to completely understand a larger social-ecological system. Instead, cross scale interactions in complex adaptive systems generate emergent behavior that cannot be predicted based on observations at a single scale, or even based on independent observations at multiple independent scales (Peters et al. 2004, 2007). Many surprises emerge from social-ecological processes interacting across scales. For example, transplanting European-style agriculture from the eastern United States to ecosystems that featured deep-rooted native grasses and highly variable rainfall has led to large-scale drought in North America and Australia (O'Gorman et al. 2016; Sayre 2017). Together, these features of social-ecological systems create a need for better information flows and coordination amongst actors at different scales not for perfect predictive capacity, which may not be possible, but for better synthesis towards general principles.

Attempts to build bridges between global sustainability challenges and local realities have resulted in frameworks that synthesize and draw conclusions about, for example, vulnerability in sustainability analysis (Turner et al. 2003), the role of ecosystem services in poverty alleviation (Daw et al. 2011), or how to improve collaborative management arrangements (Cinner et al. 2012). In recent years, several research networks have tried to address widespread sustainability challenges, including the Programme on Ecosystem Change and Society (PECS); the International Long-Term Ecological Research (ILTER) network (Maass et al. 2016; Mirtl et al. 2018); and a variety of pan-European networks, including OPERAs (Ecosystem Science for Policy and Practice, 2012–2017), OpenNESS (Operationalization of Natural Capital and Ecosystems Services, 2012–2017) and ESMERALDA (Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking, 2015–2018). Such projects include research in dozens of place-based case studies, linking academic and applied sectors, imbued with methodological innovation, and synthesized for common lessons. These, and other large European networks, have fueled the collaboration necessary to develop a common international classification system for ecosystem services (CICES), which has in turn become a key piece of research infrastructure to facilitate ecosystem service work across borders and languages (Haines-Young and Potschin-Young 2018). Importantly, these efforts have led to policy changes to improve ecosystem monitoring and governance, demonstrating the value of a research network approach to progress on such cross-cutting issues.

In this paper, we use ResNet, a new PECS regional network based in Canada and funded by the Natural Sciences and Engineering Research Council of Canada, to explore how research on a set of place-based case studies can benefit from the strengths of idiographic place-based research while still drawing more general conclusions for large-scale policy and decision-making by synthesizing across the case studies. ResNet sea- and landscapes are unified by their common interest in trade-offs among ecosystem

services that often result from management choices in working landscapes (defined here as landscapes whose primary use is for the delivery of provisioning ecosystem services such as food, timber, or energy).

Challenges for scaling up and generalizing place-based social-ecological research

In this section, we explore six challenges that impede our ability to draw general conclusions from place-based sustainability science (Figure 1). The first two challenges emerge from the difficulties of attempting to apply lessons learned from research at similar locations, that is, to transfer knowledge learned in one landscape to another target landscape due to:

(1) the limited transferability of new knowledge to other local cases given the importance, and broad variety, of context in place-based research (Kittinger et al. 2014; Balvanera et al. 2017);
(2) logistic and systemic issues, including a lack of infrastructure for sharing and archiving case study data, difficulties with allowing 'outsiders' access to local partners (involving relationships that may have been forged over time or that are fraught with sensitivities), limited funding and personnel allocated to such bridging activities, and decision-making institutions constrained to specific disciplines or locations (Mooney 2016).

Four additional challenges arise from the difficulties of maintaining the unique benefits of place-based research when aggregating to larger scales:

(3) the need to assess the extent to which local cases are representative of, or applicable to, regional or national situations (Kittinger et al. 2014);
(4) the difficulty of integrating across knowledge systems at larger scales, in part due to lack of credibility of local and traditional knowledge at larger scales (Balvanera et al. 2017);
(5) the differences in timelines and priorities of local social-ecological science versus national and international decision-making (Holzer et al. 2018); and
(6) the differences among actors and power relations among actors at different scales (Berbés-Blázquez et al. 2016).

We examine each of these challenges, and suggest some potential solutions, below.

1) *The challenge of limited transferability*

Locally important but unique (*idiographic* or *idiosyncratic*) features of social-ecological systems can limit the generalizability of findings from any given location and thus the transferability of findings from one landscape to another. Global issues are typically either common to multiple places or important to actors who function across many places (e.g. multinational corporations). The issues addressed in any given place-based social-ecological study may only be relevant to that place, or in a particular way associated with one place, making knowledge gained difficult to transfer to other places. For example, can the lessons learned from studies related to draining Canadian Prairie 'pothole wetlands' for agricultural management be applied to wetland management in Québec's agricultural regions, where small prairie wetlands do not exist but much of the landscape is wet? These problems plague even the 'gold standard' of randomized controlled trials; it can be hard to know when even the most rigorously measured and documented policy effects are generalizable outside the context in which they have been studied. Additionally, it can be difficult to abstract issues from a particular place to ensure relevance elsewhere. Take, for instance, the issue of wildlife damage to local agriculture and how to address this human–

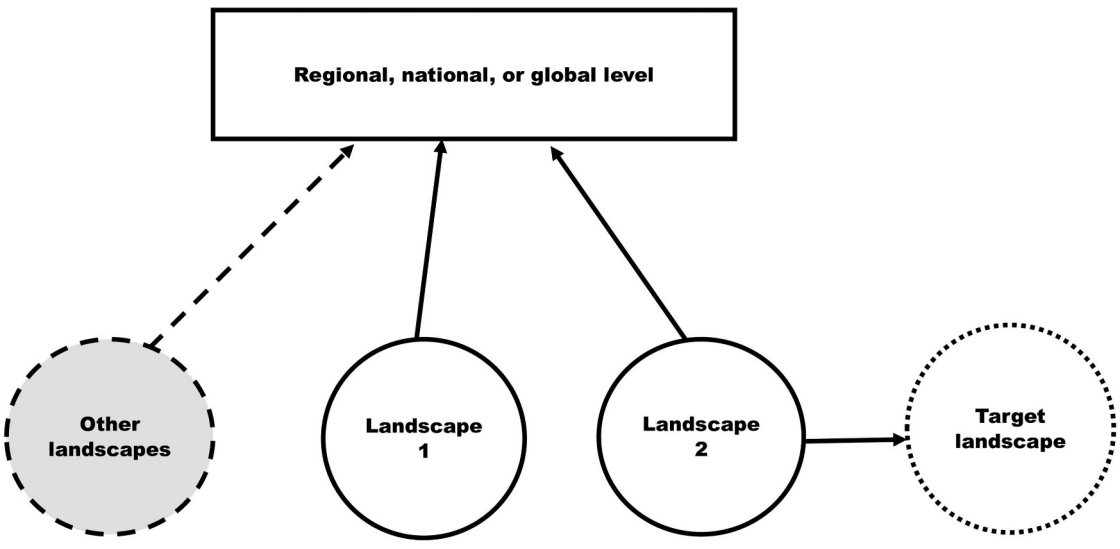

Figure 1. Research from individual ResNet landscapes may be transferred directly to other similar target landscapes. Research results may also be aggregated, perhaps in combination with other data sources and case studies, to support decisions at regional, national and global levels.

wildlife interaction. The problem, and the solutions, may be very different in the East African context where elephants raid crops, causing significant problems (Naughton-Treves and Treves 2005), compared to the upper midwestern United States, where deer browse, traffic accidents, and transmission of disease, are the bigger human–wildlife interaction issues (Rooney 2010). Such contextual differences make it difficult to identify general (aka *nomothetic*) trends and transfer lessons from one context to another, even if both situations feature problems relevant to human–wildlife interaction.

2) *The challenge of logistics*

Several underlying logistic and systemic challenges also impede synthesis across place-based cases. For example, it is often difficult to obtain funding for research on case studies, resulting in a lack of infrastructure for sharing and archiving, critical in situations where synthesis can only be attempted once the primary research is completed. Unplanned, post-hoc synthesis can suffer because place-based research may not have collected data or proceeded in a manner that favors integration and synthesis with other cases. Limited funding may also mean that project personnel are not allocated to synthetic activities, further underlining the difficulties with cross-case synthesis. Even when funding is available and cross-case synthesis is part of the plan from the start, there can be difficulties. For example, if researchers have spent years developing a relationship with local actors, they may be hesitant to allow 'outsiders' access to these stakeholders because the researchers fear damaging relationships by stakeholder burnout or by a poorly worded or timed request from an outside researcher.

3) The challenge of identifying cases representative of a target issue

Decision makers at regional and national levels may need to make decisions that span a variety of local contexts, setting out policies and plans that address the most important issues at those larger scales and that respond to typical cases. For example, national decisions about carbon storage and greenhouse gas emissions influence regional and local forestry management in many places across a country, even if those places feature different kinds of forests under different ownership with different objectives, from large crown forests with industrial leases to community-managed forests to small-scale private woodlots. To ground decisions in evidence, regional and national decision makers may turn to researchers with local expertise to provide assurances that results from a study in one place are indeed representative of the regional or national picture. However, evaluating the extent to which local ecological and social circumstances can be defensibly extrapolated is difficult in a complex social-ecological system (Bennett et al. 2021b; Peters et al. 2007). Some ecosystem services, such as agriculture and timber production, are fairly easily aggregated, while others, such as regulation of water flows or recreational experiences, may be highly non-linear, or simply impossible to scale up in a meaningful way. Furthermore, place-based research typically develops around locally relevant issues that may not align with national or global ones. Locally viable solutions may be greatly affected by context or not relevant in other contexts. Place-based research inherently calls for tailoring research protocols to the specific context of the case, including ways to incorporate local, traditional and ecological knowledge. But scaling up calls for common research protocols to facilitate comparison, which can be difficult to ensure when also trying to tailor a research protocol to a specific context.

4) The challenge of knowledge integration

Combining different types of knowledge is increasingly understood to be a key part of improving environmental governance (Tengö et al. 2014). Although methods for such integration are being developed as part of place-based social-ecological science, it can be difficult to do so effectively at larger scales, in part because of the need to integrate more, different, and sometimes conflicting, knowledge systems at larger scales. Additionally, integration can have the outcome of focusing on places where social and ecological research agree, rather than where they do not (Sherren and Darnhofer 2018). While researchers increasingly recognize the value of local ecological knowledge, knowledge integration has remained challenging, especially due to tensions and competing or unclear objectives of integration processes, and the dearth of substantive, proven processes. Indeed, the very co-production of knowledge that strengthens place-based research can impede aggregation because of the time and energy demands of capacity building and involvement of different actors (Balvanera et al. 2017). In addition, local actors can build credibility through in-person interactions that create strong relationships between researchers and people who live in research loci, the logistics of this can become difficult or even impossible at regional, national, or international scales. Trust and trustworthiness, essential at local scales, take time to build (Axelsson et al. 2013; Stern and Coleman 2015); bridges and commonalities can be easier to establish at a more abstracted larger scale where interpersonal trust plays less of a role in decision-making. The time required to develop trust and work with key actors in local research may mean that results come too slowly or too late to address an arising global or national issue that requires quick implementation of a policy. Indigenous communities may be legitimately concerned about the use of their knowledge by outsiders (Shepherd and Persad 2011 in Balvanera et al. 2017). Finally, traditional ecological knowledge may

also have less influence in larger-scale contexts where scientific knowledge and formal sanctions are often assigned more importance (Gómez-Baggethun et al. 2013).

5) The challenge of different time scales and priorities

Much like some maps show small areas in great detail, while others are able to cover large areas by smoothing out detail, place-based research is generally focused on exploring a small case or shorter time frame in great detail. Much of that detail would be illegible if we tried to retain all of it while increasing the spatial extent or time frame, so researchers must make conscious decisions about what details are essential to retain (because they are still meaningful at a larger spatial or temporal extents), and what can be safely ignored. What to retain is not always obvious because priorities are different for place-based cases than for larger regions or nations, and because time and spatial scales are often intertwined, with slower processes more easily detected at larger spatial scales, while faster processes are sometimes more obvious at smaller spatial scales (Holling and Gunderson 2002). Adaptive management may thus be more difficult at larger scales because the speed of most ecological processes at this scale is slower, creating more lag between management action and response. Interactions across spatial and temporal scales can also lead to unexpected system vulnerabilities that can be hard to identify based on the priorities at one scale. For example, some systems may remain stable across multiple scales for long periods of time but accumulate hidden vulnerabilities at one scale that cascade into others, making overall-system function vulnerable to external perturbation. (See Fraser 2003 for an application of these ideas to the case of the Irish potato famine.) Altogether, these features of social-ecological systems across spatial and temporal scales make linking long-term and place-based research critical yet very complex to do.

Place-based research can also be expensive in terms of time and transaction costs. In other situations, local research may not even be attempted because it is perceived to be too slow for a desired quick solution to an urgent question (McGowan et al. 2014). Additionally, national priorities may differ from local priorities. While responding to a crisis about flooding, maintenance of dykes, or management of prairie pothole wetlands may be essential to a healthy social-ecological system in a given location, these issues may not rise to importance nationally because they are only observed in a particular place or small set of places. However, if we can identify that all of these cases revolve around issues of agricultural drainage, then we can begin to know how to scale up management or policy responses in time and space. Deconstructing the essential and common elements that repeat across cases is essential to this generalization process.

6) The challenge of shifting actors and power dynamics

Finally, researchers leading place-based studies often confront the need to acknowledge and address the power dynamics at play among stakeholders. The fact that ecosystem service supply and demand and policy and management actions often occur at different spatial and political levels makes governance challenging (Willemen et al. 2012) and necessitates multi-scale governance (Berkes 2006). Any group discussion on issues of local environmental governance will encounter a plurality of perspectives and values (Pascual et al. 2017). Power relations, which may have co-evolved over time with environmental change, may underpin governance and management decisions on access, participation, and inclusion (Berbés-Blázquez et al. 2016). Researchers seeking to effectively address power relations need to recognize the dynamics at play (including those involving the researchers themselves), but also must articulate power asymmetries, showing respect for the values and needs of participants, and ultimately creating the conditions for social learning (Cundill and Rodela 2012; Ernst 2019). Such considerations and accommodations of diverse actors, already demanding in a place-based context, may become difficult or even impossible when applying lessons in a different context. Power relations may shift (Morrison et al. 2019), such as when actors who dominate governance processes at local scales may have little influence at a larger scale. It may also be difficult to determine the appropriate user, stakeholder, or decision-maker for a given issue at a larger scale. While the individual, groups, or organization responsible for decisions about land use, for example, may be obvious in a given place or case, such decisions may be made in disciplinary, administrative, or geographical 'silos', meaning that there is no single audience with whom to share findings and outcomes. For example, there may be a single decision-maker or team responsible for forest management within a county, but, scaling up, there may be different agencies responsible for forests for timber production, environmental management, and parks and recreation. There are literally dozens of government departments at different levels responsible for different aspects of coastal management in Nova Scotia (Sherren et al. 2019). Adding to this complexity is the now common occurrence of a local action driven by an organization operating at a much larger scale, such as when multinational corporations receive permission to extract resources in a particular location.

Summary and implications of the six challenges

Given the obstacles of conducting multi-scalar research posed by these six challenges, we turn to Balvanera et al. (2017) who call for more research on 'why, when, and how insights from a particular place and context can be exported to other analogous scales, or scaled up at larger

spatial or institutional and governance scales'. In this paper, we are concerned with how the uptake of place-based understanding in other contexts and to larger scales can be done with sufficient attention to the uniqueness of each case study and the local actors there and to cross-case comparison and learning. We see these challenges as an opportunity for networks of researchers to build relationships to work with local partners on social-ecological case studies. In doing so, such partnerships have the potential to achieve both the benefits of place-based research (i.e. the idiographic paradigm of research) *and* ensure that general trends are identified and transferred to different scales (i.e. the nomothetic style of research). Such networks also make it easier to build transdisciplinary teams because a larger team means it is possible to bring in a mix of participants with a corresponding variety of skills and expertise. Global efforts focused on networks of place-based social-ecological research, including PECS, have developed frameworks, capacity-building tools, and a global community of practice to address these and related challenges (Norstrom et al. in prep for this issue).

Building on existing efforts in place-based social-ecological science, including networks like PECS, a new network of Canadian scientists designed to integrate place-based research across six exemplar sea- and landscapes will develop data and knowledge relevant to managing those and other Canadian working landscapes for sustainability. This network, known as ResNet and funded by the Natural Sciences and Engineering Research Council of Canada (NSERC), will explore how networks of place-based studies can draw on lessons from the first ten years of PECS and help fill gaps in our understanding about how to scale up place-based social-ecological research. The motivating question at the heart of the ResNet network is: how can we effectively employ ecosystem services to improve governance of working sea- and landscapes through a series of place-based studies across Canada?

ResNet as an illustrative example of networked, place-based studies

ResNet is a network of scientists and partner-stakeholders working on place-based, co-created social-ecological science in six landscapes across Canada. It is applying "translational ecology", also sometimes called knowledge-to-action science (Matson et al. 2016; Enquist et al. 2017) or post-normal science that attempts to break down traditional barriers between 'experts' and 'lay people' (Funtowicz and Ravetz 1993). In this way, ResNet is made up of researchers committed to building links with local communities and pushing scientific knowledge to action. Where traditional science might aim for 'transfer and translate' science, in which scientific results are 'translated' for use by decision-makers, or even a 'trickle down' model, where scientific results will be taken up by decision-makers with no need for additional work by scientists (van Kerkhoff and Lebel 2006), translational ecology calls for engaging decision-makers early in the process on question development and research design (Matson et al. 2016). In other contexts, this has also been called transdisciplinary research (Lang et al. 2012).

In ResNet, we use a translational ecology approach to transform Canada's capacity to monitor, model, and manage its working sea- and landscapes and all the ecosystem services they provide for long-term well-being and shared prosperity of all Canadians in a way that reflects the fundamental inter-relationships among services, sectors, and landscapes. Importantly, participating case studies in ResNet are working sea- and landscapes, that is, areas for which people have determined that a fundamental purpose is providing a provisioning ecosystem service such as food (e.g. crops, livestock, or fish), timber, or energy. This defining feature of ResNet links the network through a common focus on working landscapes and a guiding assumption that human impacts are a defining, integral part of landscapes. In working landscapes, the strong management emphasis on provisioning ecosystem services can sometimes incur unexpected and unwanted trade-offs that reduce the provision of some key ecosystem services, such as recreation, carbon sequestration, or biodiversity (Braat and De Groot 2012). Understanding how to make better decisions around trade-offs, including avoiding them where possible, and mitigating or coping with them where avoidance is not possible, is a common concern linking our landscapes.

Within this context, ResNet aims to:

- develop new tools for estimating ecosystem services outcomes of natural resource use and governance decisions for multiple ecosystem services in Canada's land- and seascapes;
- build a structure for an ecosystem service dashboard to assess the state of Canada's natural capital; and
- create a series of models of ecosystem service provision that can be used to forecast ecosystem service outcomes of decision-making in complex systems.

These tools can improve stewardship of Canada's land- and seascapes and all the ecosystem services they provide, while fundamentally advancing scientific knowledge about these services (Bennett et al. Bennett, et al., 2021a). They will also contribute to a newly announced national scale environmental assessment, the Canadian Census of Environment.

The network was designed based on what we learned from the Montérégie Connection, an earlier PECS project, which was designed to provide information about the linkages between land use, biodiversity, ecosystem

function, and ecosystem services in the Montérégie region of southern Québec (Mitchell et al. 2015). Our results, including empirically derived ecosystem service bundles (Raudsepp-Hearne et al. 2009) highlighted the importance, in the Monteregie of southern Quebec, of forest connectivity and functional diversity on the provision of ecosystem services (Ziter et al. 2013), and showed that ecosystem service provision can vary significantly even within a single land use type in response to changes in landscape structure (Mitchell et al. 2014). We also showed that relationships between landscape structure and ecosystem services can themselves change through time (Renard et al. 2015). Finally, we learned about the essential role that 'boundary organizations' can play in designing and carrying out translational ecology projects (Mitchell et al. 2015), the importance of so-called 'soft skills' such as empathy and active listening (Caviglia-Harris et al. 2021), and we developed and practiced new methods for scenario development with stakeholders (Mitchell et al. 2015).

Drawing on that experience, and a recent Canadian Council of Academies report that declared that integration across disciplines is needed to overcome limitations of conventional approaches to natural resource management in Canada (The Expert Panel on the State of Knowledge and Practice of Integrated Approaches to Natural Resource Management in Canada 2019), we set out to bring together the benefits of place-based research with a network to improve transferability and scalability of our findings. Scientific and partnership activities of ResNet are focused on six exemplar working sea- and landscapes across Canada (Figure 2). Each landscape team is built around a key sustainability challenge for which we believe understanding ecosystem services can improve governance (Table 1).

In addition, ResNet features three themes to help with transferability and scalability among landscapes (Table 2). Those themes are focused on monitoring, modelling, and governing ecosystem services in working land- and seascapes in Canada. To support the work of both landscapes and themes, ResNet includes a platform for data archiving and sharing across the team.

Addressing challenges to drawing general conclusions from place-based sustainability science

The challenge of drawing general conclusions from context-specific, place-based science is complex. Earlier work has proposed concepts for advancing generality in ecology and in the social sciences. In ecological sciences, distributed experiments can be highly effective when the goals and questions are clear, and when data collection is standardized for comparison (Borer et al. 2014). Borer et al. (2014) noted the importance of clear ground rules for participation; simple, modular design; flexibility for additional studies; clear benefits for those who participate; starting with a critical mass; and a plan for data management.

Researchers tackling the questions of social-ecological science need to focus on the complex interactions between social and ecological aspects of cases. To do this we do draw on PECS experience with social-ecological cases and issues of comparability, including the triple-"S" (scientific rigor, societal impact, and self-care) identified by Sellberg et al. (2021); integration by 'place, case, and process' (Fischer et al. 2014; Sherren et al. 2010; Fischer et al. 2021); understanding how context affects outcomes (Schoon et al. 2021); considering equity and beneficiaries (Sitas et al. this issue); and the role of power dynamics (Felipe-Lucia et al. this issue). We have also explored the broader literature to derive a set of possible solutions to the challenges of scaling up and transferability in social-ecological science. Table 3 summarizes the key responses to the challenges identified above, and the paragraphs that

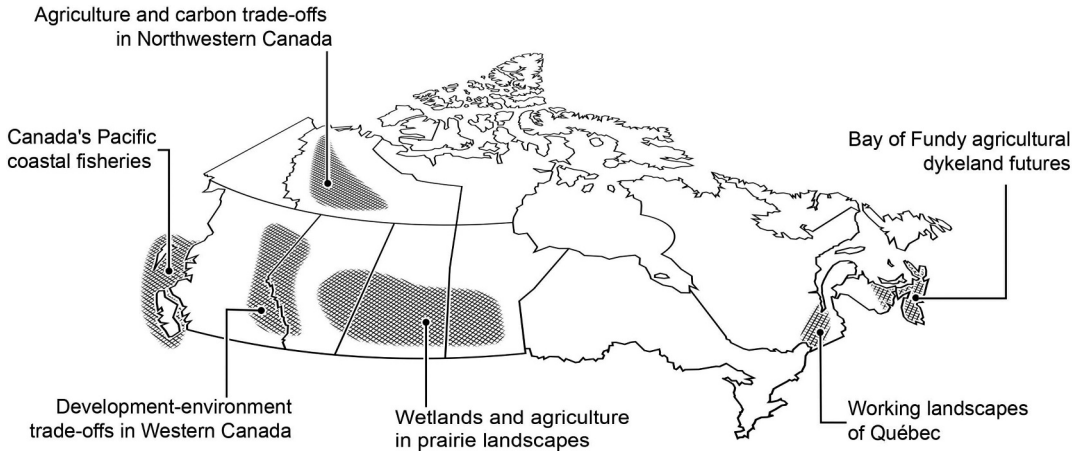

Figure 2. The six ResNet landscapes across Canada.

Table 1. Summary of the six ResNet landscapes.

Landscape	Management and Governance Issues
Landscape 1: Bay of Fundy Agricultural Dykeland futures	Evaluate the ecosystem service outcomes of maintenance, reinforcement, realignment, or removal of agricultural dykes now protecting diverse land uses but threatened by sea level rise. (Sherren et al. 2021)
Landscape 2: Working landscapes of Québec	Reconcile agriculture, forestry and peat extraction with the sustainable provision of non-extractive ecosystem services (Cimon-Morin et al. 2021)
Landscape 3: Wetlands and agriculture in prairie landscapes	Explore decision-making regarding key ecosystem service trade-offs among farmers and landowners (Minnes et al. 2020)
Landscape 4: Agriculture and carbon trade-offs in Northwestern Canada	Evaluate the trade-offs between new food production opportunities brought about by climate change resulting in a longer growing season, and how this may release additional carbon. (KC et al. in press)
Landscape 5: Development- environment trade-offs in Western Canada	Develop spatial planning solutions for multiple forms of energy development that minimize the cumulative impacts on biodiversity and other ecosystem services.
Landscape 6: Canada's Pacific coastal fisheries	Work with Indigenous communities to link science with their governance of a complex marine system.

Table 2. Summary of the three ResNet themes and synthesis team.

Theme	Primary goal
Theme 1: Develop decision-support systems for ecosystem service governance	Develop concepts, frameworks, and methods to support more effective, participatory, multi-level governance of working landscapes in Canada. (Kerr et al. ,In review)
Theme 2: Modelling ecosystem services	Develop common tools that can help understand the ecosystem service implications of landscape management options across ResNet working landscapes. (Thierry et al. 2021.)
Theme 3 Monitoring ecosystem services in working landscapes	Develop local and regional monitoring guidelines for ecosystem services across landscapes using a set of essential variables and monitoring designs that will allow comparison across landscapes. (Firkowski et al. 2021)
Synthesis Team	Focus on integration across cases (landscapes) and among themes, and help the ResNet community identify, and stay true to, common goals and focus. Attend to issues of transferability and scaling.

follow contain more details. Figure 3 shows how, and in which contexts, ResNet will take on each challenge.

Addressing challenge 1: transferability across cases

Transferability across cases requires consistency in focus and process, while co-designed, place-based social-ecological science requires allowing as much flexibility as possible for researchers in individual cases to pursue the most meaningful questions for their actors. A common focus (Qiu et al. this issue) or common process or framework (Fischer et al. this issue) could be two important potential ways to bridge this paradox. Schoon et al. (this issue) recommend that context itself can serve as an integrator when researchers focus on understanding how specific aspects of context influence outcomes. Similarly, one can identify dimensions of the case studies that can be used to align cases along a gradient to better enable comparisons and understand transferability (Angelstam et al. 2007, 2013). Such a gradient could be environmental, economic, historical, or could describe institutions, governance, culture, or any other dimensions common among cases. Importantly, these suggestions are feasible primarily when designing a network of case-based research and might be difficult or impossible to achieve post hoc unless cases happen to share similar focus or process or to align along a significant and important gradient.

Within ResNet, all research groups have a common focus on the provision of ecosystem services in working sea- and landscapes and a shared goal of working together to create a pilot monitoring system for ecosystem services in Canada. All will follow a common process – a series of three workshops punctuating periods of on-the-ground empirical science and work with local actors. We hope that these shared commonalities of goal, focus, and process will help to create greater potential for integration across the range of places and cases within the network. At the same time, researchers in each land- and seascape will determine which ecosystem services to study, based on input from local actors, and will determine the best methods for assessment based on their expert knowledge. Across ResNet, a mix of ecosystem services will be measured using a variety of methods, so it will be difficult, if not impossible, to compare the provision of any one ecosystem service across the multiple cases. However, our goal is not to compare provision across cases, but rather to understand how ecological and social processes in each land- or seascape shape the services provided to local actors and the outcomes for well-being of different groups.

Using theory can also help transfer insights gained in one location as 'lessons learned'. For example, considerable attention in ecosystem services has been focused on the issue of trade-offs between services, and whether some kinds of management or governance can help ameliorate these trade-offs (Bennett et al. 2009) as well as on the issue of the role of natural capital in the provision of services (Rieb et al. 2017). So instead of addressing specific ecosystem services, which differ across cases, we can pay particular attention to trade-offs, and ask whether the results are relevant to all ecosystem services, or at least all ecosystem services of

Table 3. The challenges of scaling up, possible solutions, and planned ResNet actions. The first two, with blue background, are challenges related to transferability among cases; the last four are challenges related to scaling up from place-based cases to regional or national scales.

Challenge	Possible Solutions	Planned ResNet actions
1. Transferability from one case to another	Use theory as a sort of 'lending library' of concepts around which to organize and compare cases (Stern 2018)	ResNet landscapes share a common focus on the ecosystem service trade-offs incurred in many working landscapes; theories such as social learning are also leveraged
	Identify similarities in structure, variables, and context so as to enable abstracting to find commonalities for comparison across cases (Qiu et al. 2021)	ResNet landscapes share a common focus on the ecosystem service trade-offs incurred in many working landscapes
	Integrate by 'place, case, and process' (Fischer et al. 2021, (Fischer et al. 2014)) suggesting a focus on process if a common place or case cannot be found	All ResNet landscapes follow a similar process of workshops with local partners interspersed with fieldwork and other research
	Make variability part of the study design: Align cases along a gradient for comparison (Axelsson et al. 2013; Angelstam et al. 2011)	ResNet was unable to do this because cases were chosen based on existing work with local actors
2. Lack of infrastructure, funding, and personnel for bridging and synthesis	Build networks of cases, and allocate funds specifically to integration and synthesis at project outset (Angelstam et al. 2011)	ResNet themes and synthesis team are funded and integrated into the overall project from the proposal
	Assign key team members to an integration/ bridging team at project outset (Tress et al. 2006)	The three themes have expertise dedicated to scaling up, and the synthesis team to cross-case transferability
3. Identifying representative cases	Pay attention to which aspects of context are important and aim to include cases with context relevant to the larger question, engaging theory to identify concepts around which to organize cases (Sherren et al. 2010).	ResNet landscapes share a common focus on the ecosystem service trade-offs incurred in many working landscapes
4. Incorporating multiple knowledge systems at larger scales	Preserve differences as information is aggregated (Hiedanpää et al. 2011)	Ensure representation of Indigenous knowledge and case-based partners at all scales of ResNet
	Seek opportunities to generalize about the *importance* of TEK and LEK, such as identifying when use of this knowledge is important to incorporate, even when specific knowledge is relevant only in one case (Lam et al. 2020)	In some ResNet landscapes, TEK and LEK offer important insights on how to manage ES tradeoffs, such as traditional sea otter hunting techniques
5. Aligning timescales and priorities from local to national and international decision-making	Work with stakeholders at multiple scales from the very beginning (Lang et al. 2012)	ResNet's' landscape workshops are an opportunity to get key stakeholders together near the outset of the project
	Identify and be aware of mandates, objectives, and scopes of action of actors at a variety of scales (Cáceres et al. 2016)	Landscape-based workshops are an opportunity to identify mandates of key actors
	Realize that not all priorities will match, so be transparent about the plan (and timeline) to ensure that different priorities are attended to	ResNet invests in teamwork, even if that sometimes means sacrificing shorter-term productivity, including monthly meetings where stakeholders can present to researchers to facilitate alignment.
6. Shifting actors and power dynamics	Get key actors working together early in the process so solutions can be co-designed across disciplinary divides (Palmer 2012; Mooney 2016)	ResNet features at least three multi-actor workshops in each landscape, designed to create a list of key actors and bring them together.

a certain type. In the case of ResNet, rather than comparing the provision of wheat in the prairies to agricultural outputs in the Bay of Fundy, we might investigate how decisions intended to maximize the provision of food influence recreational and cultural ecosystem services like hunting and hiking. The key, of course, is not only finding the right theme to achieve a common goal, but also to have a clear, well-articulated and agreed-upon understanding of the most relevant theories. ResNet is explicitly and deliberately seeking out this sort of generalization through the ResNet themes, which help to ensure consistency and transferability across landscapes while involvement of local actors ensures local relevance. Ultimately, we aim to compare insights across landscapes at a level of abstraction where the differences in context add strength to the results rather than detracting from them.

Addressing challenge 2: logistic and systemic challenges of transferability

While social-ecological science and place-based research have become increasingly valued in recent years (Balvanera et al. 2017), *comparative* place-based social-ecological science, where multiple cases are designed for comparison and transferability, remains rare. In part, this may be because it is hard to identify mechanisms to compare studies that value the role of local context. Additionally, despite interest and advances in interdisciplinary research, few scientists have this kind of training (Chang et al. 2020), and integration can be a challenge for scientists trained deeply in particular disciplines (Bammer et al. 2020).

Part of the solution to ensuring transferability lies in allocating funding, people, and authority to synthesis and aggregation from the very start of a project

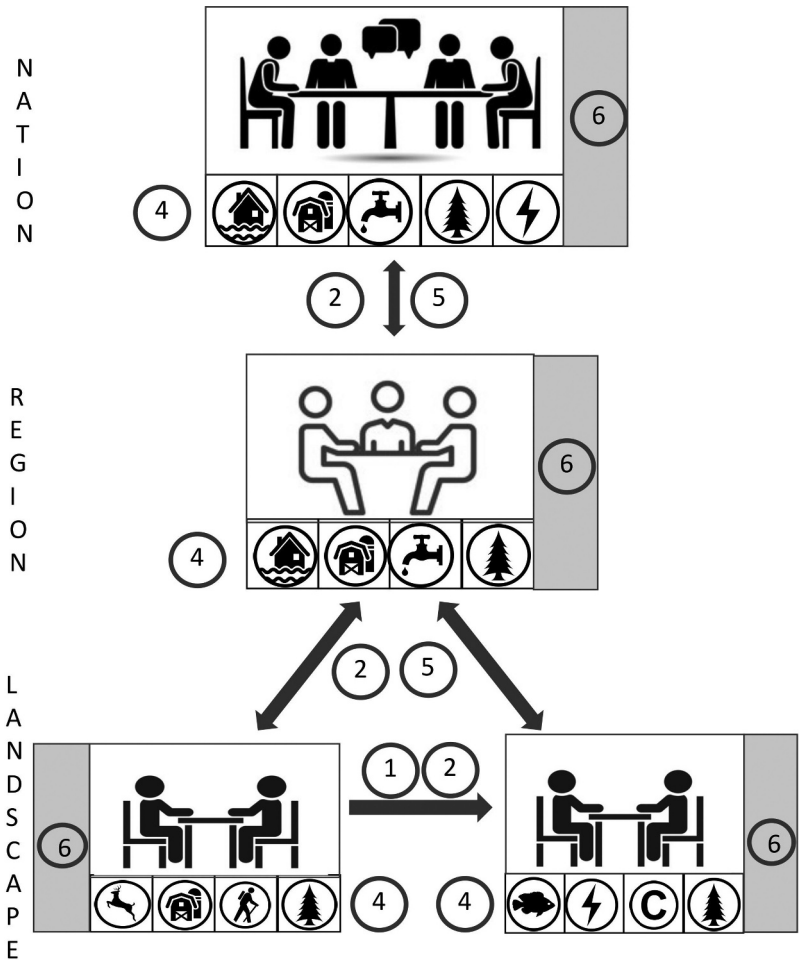

Figure 3. Each box depicts a landscape, with the top half of each box showing the actors and decisions and the bottom of each box showing the relevant ecosystem services and knowledge systems. There are 6 challenges inherent in transferring insights to other locations, and for aggregating understanding to larger scales, each of which is depicted in the Figure (1) Transfer from one case or landscape to another. (2) Address needs for bridging and synthesis. (3) Identify representative cases (not shown). (4) Incorporate multiple knowledge systems. (5) Align time scales and priorities across scales. (6) Address shifts in actors and power dynamics.

that is seeking to achieve a synthesis across cases. This requires approaching research and practice from both 'bottom up' and 'top-down' approaches (Fraser et al. 2006). Designing networks of place-based studies may be one way to achieve better integration as this encourages thinking about integration across a set of cases from the start of a research project. In that sense, ResNet itself, as a network of cases, is an experiment in addressing the issue of systemic challenges of transferability. Further, ResNet was designed to have three independent teams in charge of three themes to develop cross-landscape knowledge on topics of critical importance to achieving our goals of modelling, monitoring, and governing ecosystem services. ResNet has also created a synthesis team composed of interdisciplinary scholars dedicated to prioritizing integration across cases and among themes, as well as for helping the ResNet community identify, and stay true to, its common goals and focus, and attend to issues of scale, transferability, and synthesis of knowledge gained.

Regarding the roles of different actors, many participants in place-based studies are rightly focused on the decisions pertinent to their place, with limited interest in whether the results can be useful in other places or at larger scales (Axelsson et al. 2013). To overcome this, ResNet depends on its network of researchers and practitioners at various levels (local, provincial, federal) and brings them together in regular meetings to help identify opportunities for sharing relevant and useful information. As a result, researchers and other relevant project members are involved in synthesis and cross-landscape planning from the outset of the project.

Addressing challenge 3: identifying representative case studies

Decision makers at regional and national scales need to make decisions that apply to many distinct landscapes, often without the personal experiences of the places and direct relationships with other actors available to decision makers at local scales. This means a shift away from

place-based knowledge to reliance on evidence from many sources, often filtered through quantitative data or statistical sampling methods. This might include shifting from depending on 'stories' and the idiosyncrasies of local context to the assessment of the distribution of different landscapes.

With these shifts comes the need to evaluate how well different place-based cases represent broader patterns and trends. These patterns may result from shared biophysical connections or external drivers, such as human activities (e.g. Qiu et al., 2021), or they may arise from similar patterns of benefits flowing to different groups of beneficiaries (e.g. Raudsepp-Hearne et al. 2009).

One of ResNet's overarching goals is increase decision-makers' awareness of important ecosystem service trade-offs, especially those decision-makers working at national scales or with responsibility for resource extraction. At times, ecosystem service trade-offs have been dismissed as being primarily one of only local interest, even though they occur in many places. This makes ResNet well-placed to find cases linked around similar issues of ecosystem services, even if the specific services vary. For example, all ResNet land- and seascapes feature complex decisions about resource extraction and its impact on other ecosystem services. This has made it easier to identify the key issues across cases, which in turn, helps us raise the issue of ecosystem service trade-offs to the national level more easily. Having multiple place-based cases and allocating time and effort toward knowledge synthesis should help us clearly identify how and when national drivers have similar impacts across landscapes, and when they are likely to have divergent impacts.

Within the ResNet network, the responsibility to attend to questions of representativeness falls mainly to the teams leading the themes and the synthesis research. In addition to the shared approach to data management for the individual landscapes, these teams will be considering national data sets, including remote sensing information and Statistics Canada Census information that provide essential context for the six landscapes. These supplementary data and analyses will provide a basis for understanding that ecosystem services are important in which landscapes, how those ecosystem services can be measured, and how the resulting analyses can support better decisions at regional and national levels.

Addressing challenge 4: integration across knowledge systems

While individual place-based cases are increasingly integrating across knowledge systems, it can be difficult to retain this integration during efforts to scale-up place-based knowledge. Important differences in local ecological knowledge should be preserved, even as knowledge is applied at larger scales, and as generalities are sought. One important general principle is to empower Indigenous and other under-valued forms of knowledge, especially as we scale up results to larger scales where it might be ignored (Lam et al. 2020). This might be done by seeking out generalities across cases, similar to the methods suggested for addressing scaling up local cases in general. Others have suggested use of particular methods that more easily incorporate different ways of knowing, such as scenario development (Pereira, et al., 2021).

ResNet has put in place several systems to incorporate multiple ways of knowing as we draw conclusions across our cases. We will use scenario development to consider possible futures in all six landscapes so that our integration scales all the way through our project (Oteros-Rozas et al. 2015). We have also sought to ensure that Indigenous and other local voices are not overpowered by mainstream scientific ones by actively seeking and empowering Indigenous participation and participation of other case-based actors in all aspects of the project, including on our Advisory Board and on key governing committees.

Addressing challenge 5: disparate timescales and priorities

Since issues of local importance may differ from national priorities, it is critical to work with stakeholders from multiple scales from the outset to collaboratively define the problem to be addressed. Lang et al. (2012) suggest that working with actors from multiple scales can generate buy-in at multiple scales at the very outset of a project. They further suggest that this can be done in a way that balances contradicting claims of relevance and importance, co-designing a project from the very beginning with a common goal. It may also help to be aware of the different mandates, objectives, and scopes of action of actors at a variety of scales (Cáceres et al. 2016). Some actors, such as owners of family farms or Indigenous peoples with deep historical roots, may have concerns and objectives that have long and multi-generational histories. Across a landscape, actors may focus on very different time scales into the future, ranging from next year's harvests to projections of ecological or social trends extending decades or more.

Furthermore, building on existing relationships can provide a head-start and serve as positive examples for other cases (Angelstam et al. 2011). In ResNet, we took advantage of four cases that were well established, and brought on two new cases chosen to round out a variety of ecological and social criteria we wanted to address, such as learning to work with both local and scientific knowledge, focusing on working landscapes and the trade-offs between

provisioning and other types of ecosystem services, and understanding how different services convey well-being to different groups of people.

Addressing challenge 6: changing actors and power dynamics

Power dynamics are interwoven into the decisions, policies, behaviors and practices that shape social-ecological systems, and, as a result, social-ecological scientists need to understand interpersonal and inter-institutional interactions to develop recommendations, especially regarding co-designed research. When it comes to the aggregation of data, understanding power dynamics becomes even more complex, as the people who hold power at one scale will often be different to the ones holding it at another; the definition of relevant scales is also a social and political matter, and therefore contested (Bulkeley 2005). Researchers themselves are embedded in this complex social-ecological web; in a paradigm of problem-solving science, scientists are encouraged to conduct research using participatory processes and in a transparent manner (Enquist et al. 2017). Scientists increasingly accept the need to acknowledge their own positions and biases as well as how these may influence research, or even the communities, in which they work (e.g. Cheng and Randall-Parker 2017). Power asymmetries also shape ecosystem governance (Vallet et al. 2020). Future work should further advance understanding of power dynamics in ecosystem governance and emphasize providing clear and feasible guidance (that is feasible to implement) to promote equity and fairness. ResNet is exploring many methods for attending to power dynamics, including the power dynamics that can exist between researchers and the public with whom we work, starting with simply being aware of these dynamics and their potential to influence both process and outcomes.

Concluding thoughts

Place-based social-ecological science is an important way to bring the urgency of sustainability challenges, and their possible solutions, to a scale at which the science can be concrete and solutions implemented. But the urgency of sustainability, and the complex and often unpredictable outcomes of interacting locations (Bennett et al. 2021b) requires that we scale up and synthesize across cases. The challenges in doing so are non-trivial, but not intractable. Making accurate predictions for complex and evolving systems based on a set of aggregated case studies may not be feasible, but, as we suggest above, other kinds of generalizations are possible and may help other researchers ask better questions and may also help managers achieve more flexible and sustainable results.

Thus far, much place-based social-ecological science has been undertaken case by case, with the assumption that the high importance of local context makes generalizing and theory development difficult or even impossible. Ecological research suggests that a purpose-built network of sites (rather than post hoc analysis of independent studies) may help to address many of the problematic issues from the start because a network can be designed to have clear shared goals and questions, have cases that follow a similar process, and have clear ground rules for participation (Borer et al. 2014). In this paper, we shared our reflections on how our new national network of place-based social-ecological research landscapes will attempt to address those six challenges so we can reap the benefits of place-based research while integrating to larger scales through a network of cases.

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