Received: 15 January 2019 | Revised: 31 March 2019 | Accepted: 2 April 2019
DOI: 10.1111/csp2.44

PERSPECTIVES AND NOTES

Conservation Science and Practice
A journal of the Society for Conservation Biology
Open Access
WILEY

Systems thinking for planning and evaluating conservation interventions

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Funding information
Margaret A. Cargill Philanthropies

Abstract

As conservation shifts to meet the challenges of our globalized world, approaches for planning and evaluating interventions must evolve to account for the increasing complexity of conservation problems and the dynamic, multiscalar relationships between humans and the environment. Systems thinking offers approaches that could help conservation be more adaptive, transparent, and evidence-based. Using case studies and the literature, we trace the evolution of systems thinking and demonstrate how systems mapping could support the process of planning and evaluating interventions. Systems mapping helps disentangle the context of conservation and encourage collaborative planning that integrates diverse views. It can also change the way interventions are characterized and communicated by emphasizing the systems targeted for change as opposed to actions. Last, it can encourage evidence-based decision-making by identifying indicators attune to complexity, prompting discussion on knowledge gaps, and filling gaps through qualitative mapping or computational modeling. Integrating systems thinking in practice will help practitioners foster the capacity for learning and adaptation required for conservation to deliver global results.

KEYWORDS

biodiversity conservation, causal loop model, complexity, conservation interventions, conservation planning, monitoring, evaluation, and learning, systems mapping, systems modeling, systems thinking

1 | INTRODUCTION

Humanity is a driving force of global change (Crutzen, 2002). The acceleration of anthropogenic change has significant consequences on biodiversity (Butchart et al., 2010) with drivers such as climate change threatening irreversible changes to human and natural systems (Intergovernmental Panel on Climate Change, 2014). In response, conservation is embracing interventions that target interconnected systems on global scales: Market, policy, and behavioral interventions increasingly complement place-based approaches, diversifying the way conservation organizations plan, implement, and evaluate. The beliefs and motivations held by practitioners have also evolved (Sandbrook, Scales, Vira, & Adams, 2010) with more diverse perspectives of conservation problems and solutions in existence.

Defined in many ways (Arnold & Wade, 2015), *systems thinking* can be described as a way of thinking and understanding that considers the elements, interconnections, and function or goal of things (Meadows, 2008). While acknowledged as important for natural resource management (Bosch, King, Herbohn, Russell, & Smith, 2007; Nguyen & Bosch, 2013), approaches to conservation planning and evaluation that fully embrace systems thinking from project inception through implementation are few. The importance of addressing the root causes of biodiversity loss has been recognized (Wood, Stedman-Edwards, & Mang, 2000) yet tools for conservation intervention planning and evaluation encourage a focus on reducing threats (Conservation Measures Partnership, 2013). Though they have demonstrated success in supporting practitioners (Redford, Hulvey, Williamson, & Schwartz, 2018), tools that emphasis threats can distract from an iterative, holistic understanding of the systems that generate threats. This can inadvertently lead to interventions that do not explicitly address the dynamics and structures of systems that create conservation problems, adapt to system dynamics, or account for the diverse views of actors within systems. Ignoring the complexities of systems and system actors when planning and evaluating conservation creates risk, and can increase the chances of misdiagnosing conservation problems, or developing solutions with perverse outcomes that undermine the ability to deliver conservation results (Polasky, 2006; Larrosa & Carrasco, 2016). While scholars have studied how transformative change can create desirable social-ecological systems (SES) (Cinner & McClanahan, 2015; Scoones et al., 2018), entry points for mainstreaming systems thinking into conservation practice remain unclear.

In this article, we introduce systems thinking and its utility to conservation, and demonstrate how systems mapping can support planning and evaluating conservation interventions through two illustrative case studies and the published literature. We conclude by highlighting opportunities for integrating systems thinking into practice.

2 | FUNDAMENTALS OF SYSTEMS THINKING

A system is defined as "a regularly interacting or interdependent group of items forming a unified whole" (Merriam Webster, 2019). How items are organized and interconnected produces a system's structure, that in turn, determines a system's behavior. System behavior reveals itself as a series of events over time (Meadows, 2008). The planet is made of large systems and subsystems, from forests to individual trees and from global to household economies. Clear boundaries rarely exist between one system and another, and the practice of defining system boundaries is often subjective (Gharajedaghi, 2011; Meadows, 2008).

Ecologists have long recognized the complexity of natural systems. Theory of ecological resilience incorporated systems theory with ecology (Holling, 1973) and laid the groundwork for scholars exploring the dynamic nature of ecological systems. Building off ecological resilience, the SES concept later emerged, which assumes human and natural systems are coupled and interdependent (Folke, Berkes, & Colding, 2003; Ostrom, 2009). SES research continues to generate insights on the dynamics of human and natural systems, and incorporates concepts from complex adaptive systems theory like nonlinear dynamics, thresholds, uncertainty and surprise, and the way periods of slow change interact with rapid change across scales (Preiser, Biggs, De Vos, & Folke, 2018).

Systems thinking also has a long history in and across disciplines such as psychology, system dynamics, cybernetics, and engineering. Systems thinking can be described as a *transdiscipline*, or a field of inquiry that crosses disciplines, allowing for a transfer of methods and work across boundaries (Bosch et al., 2007). Senge called systems thinking a discipline for "seeing wholes," and a framework for seeing interrelationships rather than things, and patterns of change rather than static snapshots (Senge, 1990). Systems thinking is promoted as both a methodology and set of tools that can deal with complexity, ambiguity, and help understand underlying structures and divergent beliefs and values in the world (Maani & Cavana, 2007). Theorists say that systems thinking in practice should include long-term planning, a recognition of feedback loops and nonlinear relationships between variables, and encourage collaborative planning across areas of an organization (Kopainsky, Alessi, & Davidsen, 2011). Across domains of complex systems study, consensus has emerged that integrating ways of understanding systems is critical for tackling the problems we face in an increasingly interconnected world (Meadows, 2008; Senge, 1990; Sterman, 2000).

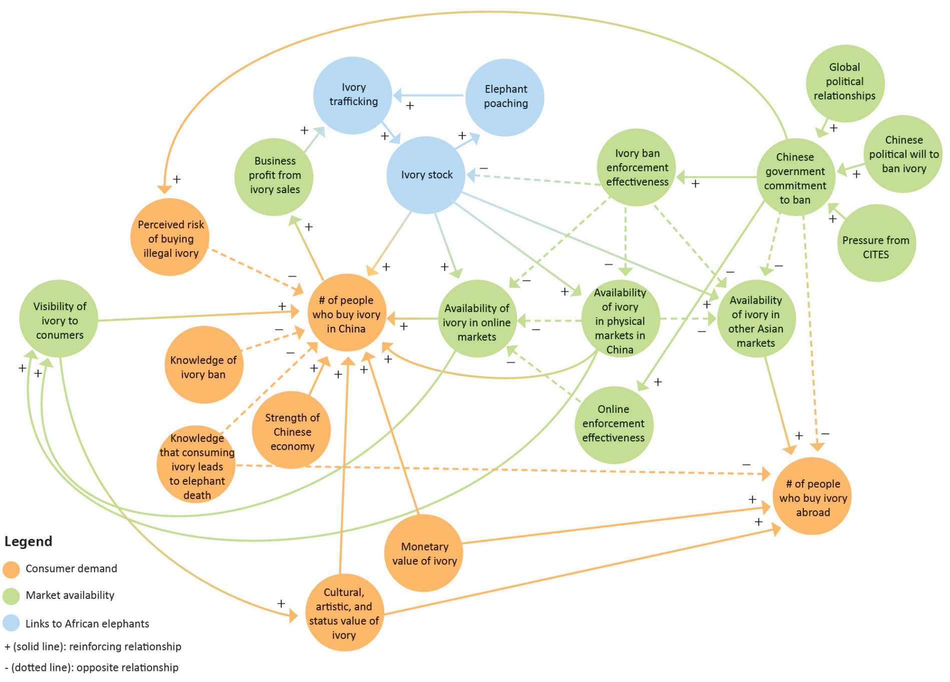
The tools, methods, and approaches used to operationalize systems thinking vary, reflecting their diverse origins in different disciplines (see table 2 in Knight, Cook, Redford, Biggs, & Romero, 2019 for a review). A common approach across disciplines is *systems mapping*, or the creation of visual diagrams that depict relationships between entities of a system. In its various forms, systems mapping can be used for example, to holistically consider different mental models of systems (Moon et al., 2019), explore issues of scale (Bosch et al., 2007), and inform computational models that provide insights on the dynamics of complex systems (Sterman, 2000). Systems maps are flexible and can vary in how they are developed, the types and ways relationships are depicted, and the different ways maps are used to inform decision-making (see Table S1 for examples).

BOX 1 Systems mapping to inform strategic planning for wildlife conservation

A systems mapping process was carried out with a team seeking to understand the dynamics of and communicate about an initiative focused on ivory demand reduction. A causal loop model was developed by the first three authors and used as a starting point to identify and discuss dynamics surrounding ivory demand in China. Over several months, the authors reviewed and revised the map with team members involved in the initiative. Throughout the process, discussions focused on how to define components of the map, important dynamics to add or remove, how to measure nodes in the map, and where evidence was either lacking or contrary. The final product communicated the initiative's strategy as a series of system maps (one pictured below). The product—a virtual map (https://wildlife.kumu.io/closing-asias-ivory-market) was used in different meetings and workshops to prompt discussion around and communicate the initiative's strategy with stakeholders, including donors and senior management.

The process of creating the map differed from conventional approaches to developing theories of change (via logic models) in that it placed a greater emphasis on the dynamics that generate the problem, and less on the initiative's activities. The process of creating the map encouraged debate on the boundaries of the system, the dynamics that drive the problem, and how the intervention's activities influence the trajectory of the system. When activities were discussed, it was always within the context of the system's dynamics. The process helped the team come to a shared understanding on why the initiative focused on demand reduction given central feedback surrounding demand. And finally, the virtual map helped communicate the importance of focusing monitoring efforts on human behavior as opposed to elephant populations given the complex dynamics of the system.

Within the broader organization, the process was framed as a pilot and helped to start internal discussion how systems mapping can encourage understanding conservation system dynamics, appropriate actions, and the selection of indicators. The framing as a pilot also gave freedom to the team to test and explore different ways to facilitate the process on different scales. Future efforts for systems mapping will focus on engaging with broader stakeholders early in the process, modeling potential system trajectories, and using maps to refine and adjust monitoring frameworks for specific initiatives.

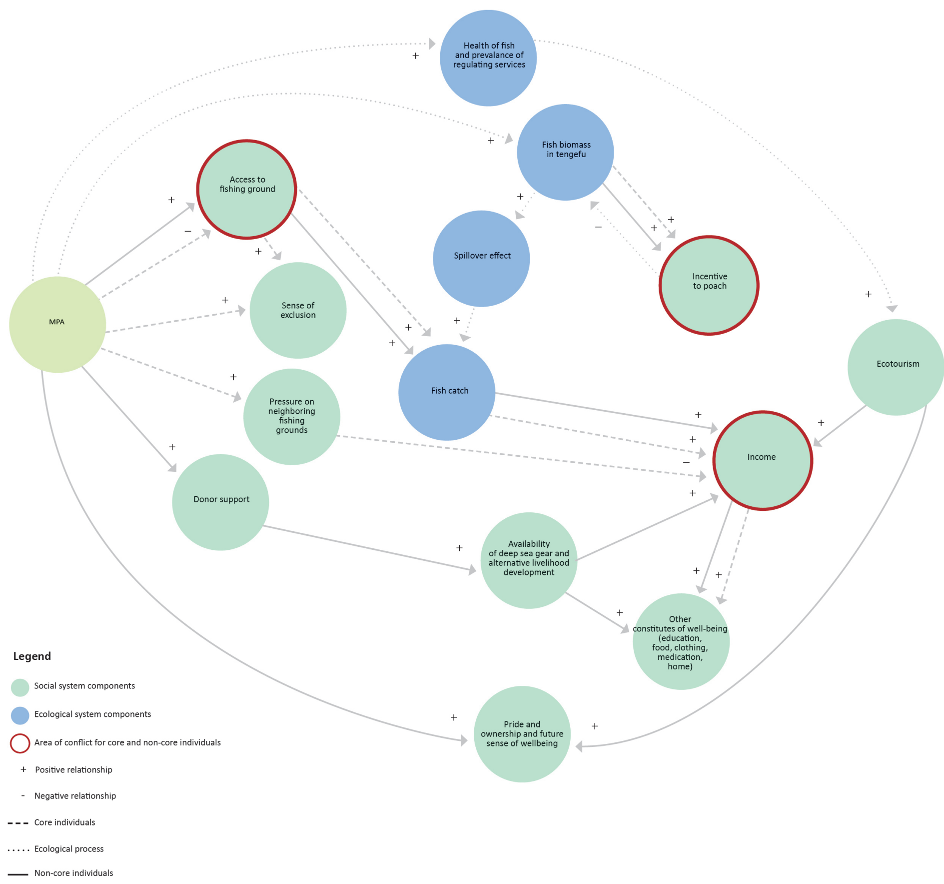


BOX 2 Systems mapping to visualize disaggregated impacts of conservation interventions

In a study by Mahajan and Daw (2016), a systems map was used to communicate how different stakeholders perceived the social impacts of new community-based conservation initiatives. The study explored two community-based MPAs on the north coast of Mombasa, Kenya, and using qualitative data, disaggregated different types of perceived impacts by different groups within the community.

To communicate research findings, a qualitative systems map that showed the flow of impacts from the community-based MPA was created from synthesized data to illustrate how different groups of fishers and fish traders (those involved in the conservation project, referred to as "core" and those not involved, referred to as "non-core") perceived the SES, and highlighted areas of conflict.

The diagram was simplified enough to make it easy to understand quickly and complex enough to convey the key message: The need to consider social dimensions of community-based MPAs. The systems map had "direction" — and showed both causal relationships between MPAs and the well-being of different groups of people, as well as dynamic relationships between elements in the system. The flexible form of the map allowed the authors to show what was more relevant for the research questions being asked, and introduced simple symbols (e.g., dotted lines, conflict circles) to annotate the map. Flexible maps like this can be used as communication tools to spark dialogue on actions to support conservation and identify appropriate places for monitoring and evaluation.



3 | OPPORTUNITIES FOR SYSTEMS THINKING IN CONSERVATION PRACTICE

To embed systems thinking in conservation planning, practice, and evaluation, approaches are needed that can help practitioners see and work within complex systems. Approaches should help practitioners and stakeholders disentangle the dynamics that generate conservation problems, incorporate and reconcile diverse perspectives, prompt discussion on trade-offs, understand system trajectories, and foster the integration of evidence and knowledge into decision-making. Using examples from two illustrative case studies (Boxes 1 and 2) and from the literature, we outline how the process and outputs of systems mapping can begin to address these needs.

3.1 | Systems mapping to support the planning of conservation interventions

Coming to a shared understanding of a problem is a fundamental first step for planning conservation interventions. Systems mapping can support this by (a) exploring the dynamics of systems, (b) facilitating a collaborative and transparent planning process, and (c) communicating the complexities of systems to relevant stakeholders.

First, approaches to systems mapping can facilitate the exploration and understanding of the dynamics of systems. For example, drawing *causal loop diagrams* (CLDs), which are qualitative models that contain variables and causal relationships in a system, can help disaggregate and make explicit the interrelationships and feedback structures between variables in a system (Sterman, 2000). Qualitative maps like CLDs can be turned into computational models, and through simulations, explore how interactions of variables in systems create emergent behavior or change over time (Bonabeau, 2002). The process of mapping and modeling can encourage conservation stakeholders to understand the complexity of the systems that create problems, explore the system's underlying structure and dynamics, and bring knowledge of system properties like time delays and feedback actively into decision-making.

For example, the demand for elephant ivory is driven by dynamics in social, political, and economic systems, and conflicting mental models of these systems perpetuate debate on how best to solve the problem (Biggs et al., 2017). Creating a systems map that makes explicit the perceived and empirically supported dynamics that perpetuate ivory demand can help (a) promote transparency and prompt debate around assumptions about the problem and possible solutions and (b) identify interventions that can work together to target the dynamics that perpetuate the problem (Box 1). Maps can be turned into computational models that allow practitioners to explore how dynamics evolve over time, integrate different types of evidence, understand potential impacts of interventions, and identify emergent properties and thresholds (Sterman, 2000). Modeling system behavior can help identify unusual pathways to conservation outcomes, perverse outcomes, and/or identify trade-offs between parts of ecological and social systems.

Second, participatory approaches to systems mapping can help stakeholders understand diverse perceptions of systems. While existing approaches for intervention development and evaluation encourage participatory behavior (Conservation Measures Partnership, 2013; Danielsen, Mendoza, Tagtag, Alviola, & Balete, 2007), they do not always acknowledge the dynamics of complex systems. And similarly, many systems approaches can be carried out in ways that are not inclusive of diverse stakeholders or participatory. Yet when done according to best practice, a participatory approach to systems mapping can create space for people within a system with diverse views and values to collaboratively define a problem—a step that is often rushed when addressing complex problems (Hovmand, 2014). Providing time and space to first recognize diverse values and views, agree on a problem frame and the boundaries of the systems that generate the problem can provide a strong foundation for understanding the dynamics of the systems and exploring pathways for change (Stroh, 2015).

In Kenya and Mozambique, researchers used systems diagrams to explore diverse narratives of change in coastal communities with representatives from government, NGOs, universities, and communities. The diagrams allowed for perceptions to be discussed clearly and openly, allowing for different perceptions on system and its desired trajectory to emerge (Galafassi et al., 2018). Processes like this can be used as a starting point for designing actions that acknowledge the diverse values and perceptions of actors in the system.

Third, systems mapping can be used to communicate the complexity of conservation problems and prompt dialogue around plausible actions and solutions. Research in Kenya shows that resource users have diverse perceptions of the social impacts of community-based marine protected areas (MPAs), influencing attitudes toward conservation (Mahajan & Daw, 2016). Results were synthesized into a systems map, published in the scientific literature and shared with an non-governmental organization (NGO) supporting local marine conservation (Box 2). The visual itself did not follow rules for conceptual models or CLDs, which gave the flexibility to communicate both causal relationships in the system and for example, the presence of conflict. This provided a way to communicate embedded intracommunity system dynamics that existed within the broader SES. The example in Box 1 demonstrates how the ivory map was used to communicate with key stakeholders the team's understanding of the problem and the surrounding system.

Systems maps can be useful tools that can help open discussions with, for example, academics who study systems, potential partners with similar goals, or funders looking to support conservation action. As practitioners in different sectors gravitate toward systems mapping (Rutter et al., 2017; The Omidyar Group, 2017), opportunities to understand tradeoffs and synergies across sectors could emerge and lead to more honest collaborations (Qiu et al., 2018).

3.2 | Systems maps for integrating evidence into conservation decision-making

Given the complexity of conservation problems, decision-making often occurs under conditions of high uncertainty. Systems mapping can shift how conservation practitioners think about and use evidence in decision-making by (a) identifying indicators that account for system dynamics and (b) identifying and addressing knowledge gaps on conservation problems and solutions.

Identifying appropriate indicators for monitoring and evaluation is often a challenging process that involves understanding assumptions about an intervention's context and *theory of change*, which is a description on how an intervention will lead to change in a system. Donors often request theories of change from grantees, many times in the form of logic models with trackable indicators. This demand together with time and resource constraints can often lead to teams ignoring the complexities of SES in indicator selection, resulting in indicators that represent a simplistic, linear understanding on how change happens. However, there is increasing recognition that to adaptively manage actions designed for systemic change, indicators must account for the dynamics of complex systems (Rutter et al., 2017; Selomane, Reyers, Biggs, & Hamann, 2019).

Systems mapping could help identify where investment in monitoring is most critical to inform decision-making, and how indicators can measure dynamics of systems. For example, systems mapping for the ivory initiative (Box 1) demonstrated the importance of measuring consumer demand instead of poaching levels or elephant populations as the initiative's main indicator given the delays and complicated linkages between elephant populations, poaching, and markets in China. The map also prompted discussion about how to measure the presence of ivory in the market and how the unit of measure (number of ivory pieces versus kilograms of ivory sold) relates to the understanding of the system. Measuring the number of pieces of ivory sold, for example, will not reflect the quantity of ivory being traded if each tusk is being split into smaller and smaller pieces. Systems mapping has a focus on making explicit the relationships and feedback in systems, which can encourage practitioners to identify sets of indicators attune to the system's dynamics, trajectory, and rates of change, as well as inform timescales for data collection and analysis.

Indicators that account for system dynamics will also influence the types of decisions practitioners can make based on evidence. Scholars have suggested that integrating knowledge on *tipping points*, or thresholds where a system risks shifting into a radically different state (Folke et al., 2004), could shift how ecosystem managers use evidence in decision-making. For example, if indicators provide an "early warning" about potential tipping points in systems (based on the knowledge of the system's dynamics), monitoring and regulation efforts could be increased when the early warning signal goes off (Selkoe et al., 2017).

The process of systems mapping can also address evidence gaps in conservation. Qiu et al. (2018) demonstrate the value of evidence-based causal chains for collaboration across sectors: Systems maps can play a similar role. Collaborative mapping processes that convene diverse stakeholders can lead to knowledge sharing and identifying gaps, while computational modeling can uncover patterns and trends in complex system behavior, contributing new knowledge on system behavior, and uncovering where knowledge may be missing or insufficient (Bosch et al., 2007).

4 | MOVING FORWARD

The cases we present and synthesize provide examples on the integration of one approach—systems mapping—in conservation, yet there is a need to learn which systems approaches are appropriate at different stages of conservation. Emerging toolkits with practical guidance (Enfors-Kautsky, Järnberg, Quinlan, & Ryan, 2018; Omidyar Group, 2017) offer promise, yet practitioners will still need the capacity to discern how, when, and why to employ different approaches. Integration of systems thinking should be done iteratively (Box 1), and in a way suited for the context of conservation problems and the needs of stakeholders.

Embedding systems thinking into conservation will come with challenges. First, conservation is political (Adams & Hutton, 2007), and while approaches like systems mapping can help integrate diverse views on conservation problems and solutions, they do not on their own remove the constraints of politics and power. It will be up to conservation stakeholders to continuously navigate power, politics, and trade-offs. And while evidence is emerging on how collaborative mapping processes impact the mental models of stakeholders (Scott, Cavana, & Cameron, 2013), there is a need to evaluate under which conditions collaborative mapping processes can encourage social learning, consensus building, and the design of transformative interventions.

Second, with their emphasis on convening diverse stakeholders and pausing activities to understand context, systems approaches may cost more in the short term compared to traditional planning approaches. Learning under what conditions a systems process is appropriate and feasible will be critical to ensure resources are used wisely. Experimenting with approaches from systems thinking will be important for this and could inform how approaches can be adapted to suit the realities and constraints of conservation practice. And last, the planning and evaluation of conservation interventions is also often tied to funding and reporting cycles. Integrating systems approaches into existing processes in institutions may increase planning fatigue and lead to misuse of or disillusion with systems approaches. Thus, successful integration would require conventional reporting patterns, often engrained in organizations, to adapt to match more fluid approaches to implementation that encourage learning, experimentation, and adaptation. Insights from development and humanitarian aid show that to embed systems thinking in practice, operations processes and funder roles and responsibilities also need to change (Green, 2016).

5 | CONCLUSIONS

Conservation practitioners and stakeholders are inherently diverse, which shapes how individuals approach planning, implementing, and evaluating interventions. Embedding approaches from systems thinking in practice could create new opportunities to learn, engage with diverse stakeholders on conservation action, and implement holistic actions relevant in our changing world. This will foster the culture of learning and experimentation required to ensure conservation can deliver global results.

ACKNOWLEDGMENTS

All authors except E.R. were supported by the Margaret A. Cargill Philanthropies. We thank the editors and two reviewers for their comments on the manuscript. Thanks to Alex Bakta for support with figures, and to the staff of WWF's Wildlife Practice for allowing us to learn with you.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Manuscript conceived by founding members of the Alliance for Conservation Evidence and Sustainability (all authors except E.R.). S.M., L.G., and E.R. developed manuscript outline. S.M., L.G., E.R., G.A., E.D., H.F., M.B.M., and M. M. drafted, edited and revised the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Mahajan SL, Glew L, Rieder E, et al. Systems thinking for planning and evaluating conservation interventions. *Conservation Science and Practice*. 2019;1:e44. https://doi.org/10.1111/csp2.44