Systems scoping

Nadia Sitas,¹ Paul Ryan² and Lisen Schultz³

¹CENTRE FOR SUSTAINABILITY TRANSITIONS, AND DEPARTMENT OF CONSERVATION ECOLOGY AND ENTOMOLOGY, STELLENBOSCH UNIVERSITY, STELLENBOSCH, SOUTH AFRICA

²AUSTRALIAN RESILIENCE CENTRE, AUSTRALIA

³STOCKHOLM RESILIENCE CENTRE, STOCKHOLM UNIVERSITY, STOCKHOLM, SWEDEN

Key methods discussed in this chapter

Social-ecological inventories, stakeholder analysis, historical, social and ecological inventories, cultural domain analysis, contextual profiling, policy scoping, literature reviews

Connections to other chapters

Conducting a systems-scoping exercise can be the precursor to many other analyses outlined in this book and is useful for identifying the key variables and components of the study. A systems-scoping exercise can help to identify what ecological and social data might need to be collected (Chapters 6–8) and whether more participatory and inclusive methods of knowledge co-production are needed (Chapters 9, 12–15 and 22). In addition, a systems-scoping exercise can identify the temporal nature of further research, e.g. whether there needs to be additional historical (Chapter 25) or future-looking analyses (Chapters 10 and 11). By developing a better understanding of the boundaries of the research through systems scoping, the researcher can then get a better idea of which further methods to select, e.g. methods to understand system components (Chapters 16–24), system dynamics (Chapters 25–28) or combinations thereof (Chapters 31 and 32).

Introduction

Which ecological and social variables should be included when trying to understand specific phenomena or issues? How do these variables interact, under what conditions and at which scale? Which knowledge types and actors are important to include? These are some of the typical questions asked when undertaking a systems-scoping exercise in social-ecological systems (SES) research. Many different methods have been used to ‘scope’ a system, but common to most is a focus on the importance of setting the boundaries of the system under investigation and identifying the system components, their relationships and issues of interest (Walker et al. 2004; Peterson 2005).

Systems scoping has been used in a number of different disciplines, from the health sciences, to social and natural sciences, to humanities, but has a strong history in strategic

SUMMARY TABLE: SYSTEMS SCOPING	
DISCIPLINARY BACKGROUND	KNOWLEDGE TYPE
<p><i>The methods in this chapter are derived from or have most commonly been used in:</i></p> <p>Environmental Science, Geography, Health Sciences, Management/ Business Studies, Public Administration/ Policy Studies</p>	<p><i>The methods in this chapter are primarily used to generate the following types of knowledge:</i></p> <ul style="list-style-type: none"> • Descriptive • Exploratory
RESEARCH APPROACH	PURPOSE OF METHOD
<p><i>The methods in this chapter originate from or most commonly adopt the following research approaches:</i></p> <ul style="list-style-type: none"> • Analytical/objective • Interpretive/subjective • Collaborative/process 	<p><i>The most common purposes of using the methods in this chapter are:</i></p> <ul style="list-style-type: none"> • Data collection/generation • System understanding • Stakeholder engagement and co-production • Policy/decision support
TEMPORAL DIMENSION	SYSTEMIC FEATURES AND PROCESSES
<p><i>The methods in this chapter are most commonly applied to the following temporal dimensions:</i></p> <ul style="list-style-type: none"> • Present (typically within the last 5–10 years) • Recent past (post-1700s) 	<p><i>While most methods can do many things, the methods in this chapter are particularly good (i.e. go-to methods) for addressing the following:</i></p> <ul style="list-style-type: none"> • SES components and linkages • Diversity • Power relations • Multiple scales and levels or cross-level interactions • Social learning • Collective action and collaborative governance
SPATIAL DIMENSION	
<p><i>The methods in this chapter are primarily either or both:</i></p> <ul style="list-style-type: none"> • Non-spatial • Explicitly spatial <p><i>The methods in this chapter are most commonly applied at the following spatial scales:</i></p> <ul style="list-style-type: none"> • Local 	

planning and associated applied fields such as environmental management and town and regional planning. More specifically in SES research, the goal of systems scoping is to explore a system from a variety of perspectives before establishing a set of key issues (past, present and future), the objectives of a study and a methodology/research design for a more in-depth analysis of particular social-ecological dynamics of interest. In addition, scoping can be used in preparation for a participatory or consultative research process to identify key actors and co-identify issues of concern or interest. Thus, systems scoping can employ a number of different research methods, such as interviews and surveys (Chapter 7), participatory data collection (Chapter 8), network analyses (Chapter 23), institutional analyses (Chapter 22) and facilitated dialogues (Chapter 9).

Social-ecological systems are complex, open systems. To better understand them, one needs to understand not only the system under consideration but also the broader SES it is linked to or embedded in, which is in itself complex. Complex adaptive systems are dynamic, evolve in response to changes in feedbacks and have thresholds and tipping points (see Chapters 1 and 2). A systems-scoping exercise should incorporate approaches that attempt to document the elements that lead to or contribute to these dynamic phenomena. However, to avoid an attempt to include everything, the complexity of the system still needs to be reduced within certain boundaries in order to enable the (co)generation of knowledge (Cilliers 2005; Scholes et al. 2013), while keeping in mind that any choice of this nature means that important interconnections and feedbacks may be missed. Due to the inherent complexity and uncertainty of SES, knowledge of the system can only be gained in relation to a particular framework (or conceptual model) that is employed. However, our conceptualisation of the system will always only be partial. Value-laden choices of what to include, and where the boundaries need to be articulated, are always involved and have consequences for how we understand the system (Cilliers 2005; Heylighen, Cilliers, and Gershenson 2006).

Scoping can refer to a stage in a larger assessment or research process (e.g. in strategic assessments like impact assessments or resilience assessments) or be a stand-alone study that is used to describe a coupled SES (Resilience Alliance 2010; Audouin 2011; Enfors-Kautsky et al. 2018). Systems scoping can also range from a narrow desk-based study to more inclusive participatory processes drawing on diverse actor conceptualisations of a system in order to unearth important issues pertaining to that system (Schultz, Plummer, and Purdy 2011). In some cases, broad participation in a scoping phase is required by law. Scoping should also always be conducted within an ethical framework that is as inclusive as possible (Watson 2010; Cockburn and Cundill 2018). A hidden assumption when conducting a systems-scoping exercise is that those leading or defining the scoping boundaries are aware of the many variables and values inherently present in the system. Here it is important to acknowledge the role of power – not only in terms of method selection but also in determining who and what to be considered or included in the system framing, how diverse values will be accounted for and who might benefit from the research (e.g. researchers, practitioners, funders) – and to highlight the importance of reflexivity in systems-scoping methodologies and approaches (Cote and Nightingale 2012; Audouin et al. 2013; Hankivsky 2014).

Systems scoping is often constrained by institutional and biophysical boundaries, e.g. a water catchment or local government area. When these institutional and biophysical boundaries are spatially different, e.g. when a national border crosses a river, scoping entails making an explicit choice between them (Ison 2008). Systems scoping is also often directed by a conceptual framework, e.g. the Intergovernmental Science Policy Platform for Biodiversity and Ecosystem Services (IPBES) conceptual framework (Díaz et al. 2015) or Ostrom's framework for analysing the sustainability of SES (Ostrom 2009). These conceptual frameworks help to set the boundaries, conditions and variables for a deeper exploratory or analytical exercise based on addressing specific questions or problems.

SES problems and questions

A scoping exercise is often one of the first steps undertaken in research in order to define the boundaries of the research and identify the key relations and dynamics between actors and ecosystems in a given SES. Systems scoping can be applied to a number of different research contexts at different spatial scales. It is very useful in helping to focus a study and outline the important issues that could be considered, and deciding which variables from different domains (e.g. social or environmental) to include. In addition to identifying the key ecological components and important actors within a system, Audouin et al. (2013) identify a number of questions that can underpin a systems scoping. These include:

- Who should be involved in defining the purpose of the study, the problem to be addressed and the skills to be included?
- What values underpin the goals and objectives of the study?
- What assumptions are made in defining the various spatial, temporal and substantive (i.e. issues to be addressed) boundaries of the study?
- What knowledge types (explicit and tacit, informal and formal) are important to include in the process of gaining an understanding of the SES?
- How can the research process, its goals and outcomes be aligned with the needs and values of those most likely to be affected by any recommendations or decisions that might come from the study?
- What is the role of power in shaping relationships and the flows of resources and benefits?

Brief description of key methods

Systems scoping involves the use of a variety of methods in order to understand key dynamics, scales and relationships of social and ecological components in SES. These methods

Table 5.1 Summary of key methods used in systems scoping

<i>Method</i>	<i>Description</i>	<i>References</i>
Literature review	A literature review is a widespread method used to review published materials that examine recent or current literature on specific topics. As part of a systems-scoping exercise, it can help to define and refine the topic of interest. It can cover a wide range of subjects at various levels of completeness and comprehensiveness, e.g. peer-reviewed literature as well as grey literature.	<i>Key introductory texts</i> Grant and Booth 2009 (highlighting the specific types of systematic reviews); Hart 2018 <i>Applications to SES</i> Binder et al. 2013; Milkoreit et al. 2018
Policy scoping	Within a systems-scoping process it is often important to identify the relevant policies that can affect the SES and the issues of interest. This can be done as a desk-based process, or through engagement of stakeholders who have knowledge of the particular policies and regulations that might be relevant.	<i>Key introductory text</i> Anderies and Janssen 2013 <i>Applications to SES</i> Anderies, Janssen, and Ostrom 2004; Kraft and Vig 2006; Garmestani 2014; Orach and Schlüter 2016

<i>Method</i>	<i>Description</i>	<i>References</i>
Stakeholder analysis	Stakeholder inventories and analyses focus on identifying important actors who have a stake in the research. They are used to gather information from all stakeholders who affect the decision-making process. These methods mostly tend not to account for biophysical components.	<i>Key introductory text</i> Reed et al. 2009 <i>Applications to SES</i> Grimble and Wellard 1997; Stringer et al. 2006; Prell, Hubacek, and Reed 2009; Petursdottir et al. 2013
Ecological inventory	Ecological inventories aim to document the biophysical landscapes of a specified system and are often compiled through field surveys, remote sensing and/or ecological mapping techniques. Ecological inventories generally omit the social processes influencing the natural system and as such are not often used in isolation in SES research.	<i>Key introductory text</i> McRae et al. 2012 <i>Applications to SES</i> Wulder et al. 2004; SANBI and UNEP-WCMC, 2016; also see Chapter 6 on ecological field data collection and Chapter 31 on ecological and ecosystem service mapping and modelling
Social inventory	Social inventories are similar to stakeholder analyses/mapping but tend not to focus on the power dimensions of the different actors in the system as much as stakeholder analyses or social network analyses and mapping.	<i>Key introductory text</i> Grimble and Wellard 1997 <i>Applications to SES</i> Barthel et al. 2005; Colding 2013; Wali et al. 2017
Social-ecological inventories	Social-ecological inventories are used to map key actors engaged in ecosystem management, their values, motives, activities, knowledge, networks and experiences over time, and while doing so to identify and select the most important actors to build trust and work with. Through engagement with key actors, important ecosystem features might be revealed, which could result in identifying additional ecosystem features to consider.	<i>Key introductory texts</i> Schultz, Folke, and Olsson 2007; Schultz, Plummer, and Purdy 2011 <i>Applications to SES</i> Schultz, Folke, and Olsson 2007; Baird, Plummer, and Pickering 2014
Historical inventory	Historical inventories aim to document important historical events in a system within a specified timeframe and are useful for understanding change and path dependencies in SES. Documenting these events can be conducted either through a literature review or in a more participatory manner, e.g. through interviews or focus groups.	<i>Key introductory text</i> Resilience Alliance 2010 <i>Applications to SES</i> Ramankutty and Foley 1999; Barthel et al. 2005; Anderson and O'Farrell 2012; Boonstra and De Boer 2014; Zheng et al. 2014
Cultural domain analysis	A cultural domain analysis is used to understand how people in a society think about and define their world. Since all cultures use some system of categories to order experience, the researcher tries to determine what categories are important to people, how these categories are arranged and what values are attached to them.	<i>Key introductory text</i> Puri 2011 <i>Applications to SES</i> Rodríguez, Pascual, and Niemeyer 2006; Buchmann 2009; Sheil and Liswanti 2006

most commonly include literature reviews, policy scoping, social, ecological, historical and social-ecological inventories, stakeholder analyses and cultural domain analysis. These methods are often used in combination with one another. A social-ecological inventory-based approach can often include social, ecological, cultural and historical characteristics. Table 5.1 provides a summary of key methods used in systems scoping.

Limitations

One of the main limitations in systems-scoping exercises concerns setting the boundaries of the research and how information on stakeholders and spatial and temporal dynamics is intentionally

Case study 5.1: Application of a social-ecological inventory to engage actors in Niagara, Canada

The Niagara region plays an important role in Canada's development, contributing to the economy through industry, agricultural production of fruit and wine, and tourism from the more than 30 million people visiting Niagara Falls annually. The unique biocultural diversity of the area has been recognised with the establishment of the UNESCO Niagara Escarpment Biosphere Reserve in Ontario. In 1998, the Canadian government commissioned a study on the impacts of climate variability on the region. At the time there was no known entity (e.g. government organisation or research institute) focusing on climate change adaptation. Baird, Plummer and Pickering (2014) sought to investigate whether the governance system for climate change adaptation could be primed by undertaking a social-ecological inventory.

The use of a social-ecological inventory seems to have been instrumental in facilitating a multi-sectoral, adaptive co-management governance approach to climate change in the Niagara region (Baird, Plummer, and Pickering 2014). The iterative and dynamic process followed six steps: preparations, preliminary identification, identification of key individuals, interviewing, reviewing and enriching the inventory, and engagement. These steps are outlined in Figure 5.1. This study focused on understanding the role of local knowledge as an important factor in understanding the SES and whether this approach could catalyse co-management approaches to assist with climate change adaptation.

Questions posed to the stakeholders in the research covered issues related to: (a) perceptions of climate change impacts in Niagara, organisational capacity for adaptation and adaptation leadership; (b) specific activities related to climate change and the rationale for these efforts; and (c) networks and relationships with other actors in Niagara related to climate (Baird, Plummer, and Pickering 2014).

The use of a social-ecological inventory-based approach as a precursor to undertaking a climate change adaptation strategy resulted in the following observations: (a) the approach facilitated adaptive co-management mainly through unearthing insights about networks and relationships, which could enable key actors and bridging organisations to be identified, (b) local sources of knowledge were revealed and gaps in knowledge illuminated, and (c) the tailoring of the adaptive co-management process was possible because the approach brought about an awareness of existing actions, desired information and differences in values that could be used in future planning.

or unintentionally included or excluded. Not acknowledging the role of power and politics and how power influences decisions in research can limit the ways in which diversity is taken into account in the conceptualisation of the system (Smith and Stirling 2010; Nayak, Armitage, and Andrachuk 2016). This diversity can include diversity of knowledge based on disciplinary biases, which can minimise the inclusion of diverse disciplinary knowledge or non-disciplinary knowledge and expertise such as local and indigenous knowledge (Van Kerkhoff and Lebel 2006; Tengö et al. 2014). Diversity can also relate to various other social categories such as gender, socio-economic status, ethnicity, religion, age and geographic positionality. Methods for better understanding how these categories intersect and influence the way in which the system and relationships between variables are framed are not always included in scoping processes

The study highlighted future avenues to test the social-ecological inventory approach. These relate to exploring how the approach could be applied in different contexts; exploring different user perceptions of the approach beyond the research community; setting up a database of studies using social-ecological inventories in order to undertake comparative analyses and promoting learning of how the use of social-ecological inventories could be enhanced in different contexts.

Figure 5.1 Phases of the social-ecological inventory (Baird, Plummer, and Pickering 2014)

(Thompson-Hall, Carr, and Pascual 2016). Power can also mediate the legitimacy of research through excluding key actors or end-users of the research, or by not being explicit about any vested interests in the research going forward (Cash et al. 2003; Clark et al. 2016).

Systems-scoping exercises are normally a descriptive snapshot of the system and its recent past. They are not normally used for explanatory purposes on their own but require additional methods to account for changes and feedbacks in system dynamics across space and time, e.g. scenario and futures assessments (Chapters 10 and 11), social network analyses (Chapter 23) or ecosystem service modelling (Chapter 31). However, systems-scoping exercises can continue to evolve as one learns more about the dynamics and key features of the system that can be used to iteratively focus the study and/or set new boundaries and conditions for research.

Resource implications

The resource implications linked to systems scoping depend on the boundaries and objectives of the specific task. They also depend on acknowledging that there are certain trade-offs and tensions that are important to consider between more technical processes compared to more social, participatory processes. If the aim is to effect change, matching quality information with a legitimate, credible and salient process has a higher capacity for fostering change.

More inclusive, participatory processes for systems scoping require extensive resources (in addition to time as a key resource). These processes typically involve hosting workshops, which includes selecting a suitable venue to use (or hire), travel and transport costs, security measures if necessary, using professional facilitators trained in systems thinking and stakeholder engagement (or undertaking training in order to run these workshops), and materials for running the workshop (see also Chapter 8 and methods for knowledge co-production and effective system change in Chapters 9–15). Depending on the context, it might also be necessary to compensate participants for their participation, either by way of monetary compensation or by providing a meal and transport. Careful attention should always be paid to the ethics of conducting participatory research, especially with vulnerable groups (Watson 2010) (see also Chapter 3).

Systems-scoping exercises often require little in terms of hardware or software when being conducted, but some form of systems-mapping software is useful in order to map out the results of a scoping exercise and capture the relationships between identified variables. These software programs can be simple (preferably open-source) programs such as Visio, MyDraw and draw.io, or more advanced software for simulation or data analysis purposes that would move beyond a scoping exercise for more analytical purposes (e.g. Vensim, Atlas.ti, QGIS, ArcGIS and Google Earth/Maps). Cameras to document specific system features (e.g. a river, place of interest, infrastructure) are useful to provide visuals of specific features for future use, but hand-drawn maps or images are also useful and sometimes easier in under-resourced contexts where access to electricity and other technology is challenging.

New directions

Given the importance of considering interconnected social and ecological components of systems, and that alternative conceptualisations of the system exist, a number of tools are being developed that provide decision-makers with frameworks to guide systems-scoping exercises. These include the Wayfinder tool (Enfors-Kautsky et al. 2018), the STEPS Pathways approach (Leach, Scoones, and Stirling 2007) and the Resilience, Adaptation Pathways and

Transformation Assessment (RAPTA) framework (O’Connell et al. 2015) (Chapter 14). New potential applications include tools that foreground the role of power and politics in systems scoping (e.g. building on Schoon et al. 2015; Berbés-Blázquez, González, and Pascual 2016) and those that try to embed SES perspectives in assessment processes, e.g. IPBES assessments (see the IPBES guide for assessments at ipbes.net/guide-production-assessments).

Transdisciplinary advances for problem framing can be useful in determining the research question and setting the initial boundaries of the research (Pohl and Hadorn 2007; Hadorn et al. 2008). The T-Lab approach provides a novel methodology for designing transformative spaces to negotiate and articulate key issues of interest (Pathways Network 2018; Pereira et al. 2018). Research using cultural historical activity theory (CHAT) can also shed more light on the relationship between the human mind (what people think and feel) and the activity (what people do). CHAT has been used as ‘a cross-disciplinary framework for studying how humans purposefully transform natural and social reality, including themselves, as an ongoing culturally and historically situated, materially and socially mediated process’ (Roth, Radford, and Lacroix 2012).

Key readings

- Audouin, M., M. Burns, A. Weaver, D. le Maitre, P. O’Farrell, R. du Toit, and J. Nel. 2015. ‘An Introduction to Sustainability Science and its Links to Sustainability Assessment.’ In *Handbook of Sustainability Assessment*, edited by A. Morrison-Saunders, J. Pope, and A. Bond, 321–346. Cheltenham: Edward Elgar.
- Enfors-Kautsky, E., L. Järnberg, A. Quinlan, and P. Ryan. 2018. Wayfinder: A Resilience Guide for Navigating Towards Sustainable Futures. GRAID Programme, Stockholm Resilience Centre, Stockholm University. www.wayfinder.earth.
- Reed, M.S., A. Graves, N. Dandy, H. Posthumus, K. Hubacek, J. Morris, C. Prell, C.H. Quinn, and L.C. Stringer. 2009. ‘Who’s in and Why? A Typology of Stakeholder Analysis Methods for Natural Resource Management.’ *Journal of Environmental Management* 90(5): 1933–1949.
- Schultz, L., R. Plummer, and S. Purdy. 2011. ‘Applying a Social-Ecological Inventory: A Workbook for Finding Key Actors and Engaging Them.’ www.stockholmresilience.org/publications/artiklar/2011-06-07-applying-a-social-ecological-inventory-a-workbook-for-finding-key-actors-and-engaging-them.html.

Acknowledgements

In addition to the wonderful reviewers of this chapter, the authors thank Michelle Audouin for her insightful comments and the Sida-funded Guidance for Resilience in the Anthropocene: Investments for Development (GRAID) project at the Stockholm Resilience Centre, Sweden for supporting this work.

References

- Anderies, J.M., and M.A. Janssen. 2013. ‘Robustness of Social-ecological Systems: Implications for Public Policy.’ *Policy Studies Journal* 41(3): 513–536.
- Anderies, J.M., M.A. Janssen, and E. Ostrom. 2004. ‘A Framework to Analyze the Robustness of Social-Ecological Systems from an Institutional Perspective.’ *Ecology and Society* 9(1): 18.
- Anderson, P.M.L., and P.J. O’Farrell. 2012. ‘An Ecological View of the History of the City of Cape Town.’ *Ecology and Society* 17(3): 28.
- Audouin, M. 2011. *Transdisciplinary Research for Sustainability: User Guide*. Council for Scientific and Industrial Research, Stellenbosch, South Africa.

- Audouin, M., R. Preiser, S. Nienaber, L. Downsborough, J. Lanz, and S. Mavengahama. 2013. 'Exploring the Implications of Critical Complexity for the Study of Social-Ecological Systems.' *Ecology and Society* 18(3): 12.
- Baird, J., R. Plummer, and K. Pickering. 2014. 'Priming the Governance System for Climate Change Adaptation.' *Ecology and Society* 19(1): 3. doi:10.5751/ES-06152-190103.
- Barthel, S., J. Colding, T. Elmqvist, and C. Folke. 2005. 'History and Local Management of a Biodiversity-rich, Urban Cultural Landscape.' *Ecology and Society* 10(2): 10. www.jstor.org/stable/26267721.
- Berbés-Blázquez, M., J.A. González, and U. Pascual. 2016. 'Towards an Ecosystem Services Approach that Addresses Social Power Relations.' *Sustainability Science* 19: 134–143. doi:10.1016/j.cosust.2016.02.003.
- Binder, C.R., J. Hinkel, P.W.G. Bots, and C. Pahl-Wostl. 2013. 'Comparison of Frameworks for Analyzing Social-Ecological Systems.' *Ecology and Society* 18(4): 26.
- Boonstra, W.J., and F.W. de Boer. 2014. 'The Historical Dynamics of Social-Ecological Traps.' *Ambio* 43(3): 260–274.
- Buchmann, C. 2009. 'Cuban Home Gardens and their Role in Social-Ecological Resilience.' *Human Ecology* 37(6): 705.
- Cash, D.W., W.C. Clark, F. Alcock, N.M. Dickson, N. Eckley, D.H. Guston, J. Jäger, and R.B. Mitchell. 2003. 'Knowledge Systems for Sustainable Development.' *Proceedings of the National Academy of Sciences* 100(14): 8086–8091.
- Cilliers, P. 2005. 'Complexity, Deconstruction and Relativism.' *Theory, Culture & Society* 22(5): 255–267.
- Clark, W.C., L. van Kerkhoff, L. Lebel, and G.C. Gallopin. 2016. 'Crafting Usable Knowledge for Sustainable Development.' *Proceedings of the National Academy of Sciences* 113(17): 4570–4578.
- Cockburn, J., and G. Cundill. 2018. 'Ethics in Transdisciplinary Research: Reflections on the Implications of "Science with Society".' In *The Palgrave Handbook of Ethics in Critical Research*, edited by C.I. Macleod, J. Marx, P. Mnyaka, and G. Treharne, 81–97. London: Palgrave Macmillan.
- Colding, J. 2013. 'Local Assessment of Stockholm: Revisiting the Stockholm Urban Assessment.' In *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*, edited by T. Elqvist, M. Fragkias, J. Goodness, B. Güneralp, P.J. Marcotullio, R.I. McDonald, S. Parnell et al., 313–335. Dordrecht: Springer.
- Cote, M., and A.J. Nightingale. 2012. 'Resilience Thinking Meets Social Theory: Situating Social Change in Socio-ecological Systems (SES) Research.' *Progress in Human Geography* 36(4): 475–489.
- Díaz, S., S. Demissew, J. Carabias, C. Joly, M. Lonsdale, N. Ash, A. Larigauderie, J.R. Adhikari, S. Arico, and A. Báldi. 2015. 'The IPBES Conceptual Framework – Connecting Nature and People.' *Current Opinion in Environmental Sustainability* 14: 1–16.
- Garmestani, A.S. 2014. 'Sustainability Science: Accounting for Nonlinear Dynamics in Policy and Social-Ecological Systems.' *Clean Technologies and Environmental Policy* 16(4): 731–738.
- Grant, M.J., and A. Booth. 2009. 'A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies.' *Health Information & Libraries Journal* 26(2): 91–108.
- Grimble, R., and K. Wellard. 1997. 'Stakeholder Methodologies in Natural Resource Management: A Review of Principles, Contexts, Experiences and Opportunities.' *Agricultural Systems* 55(2): 173–193.
- Hadorn, G.H., H. Hoffmann-Riem, S. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Pohl, U. Wiesmann, and E. Zemp. 2008. *Handbook of Transdisciplinary Research, Volume 10*. New York: Springer.
- Hankivsky, O. 2014. 'Intersectionality 101.' The Institute for Intersectionality Research & Policy, SFU, 1–34.
- Hart, C. 2018. *Doing a Literature Review: Releasing the Research Imagination* (2nd ed), 1–381. Thousand Oaks: Sage.
- Heylighen, F., P. Cilliers, and C. Gershenson. 2006. 'Complexity and Philosophy.' ArXiv Preprint Cs/0604072.
- Ison, R.L. 2008. 'Systems Thinking and Practice for Action Research.' In *The Sage Handbook of Action Research Participative Inquiry and Practice* (2nd ed), edited by P.W. Reason and H. Bradbury, 139–158. London: Sage.
- Kraft, M.E., and N.J. Vig. 2006. 'Environmental Policy from the 1970s to the Twenty-First Century.' In *Environmental Policy: New Directions for the Twenty-First Century*, edited by N.J. Vig and M.E. Kraft, 1–33.

- Leach, M., I. Scoones, and A. Stirling. 2007. 'Pathways to Sustainability: An Overview of the STEPS Centre Approach.' *STEPS Approach Paper*. Brighton: STEPS Centre. https://steps-centre.org/wp-content/uploads/final_steps_overview.pdf.
- McRae, L., B. Collen, S. Deinet, P. Hill, J. Loh, J.E.M. Baillie, and V. Price. 2012. 'The Living Planet Index: Biodiversity, Biocapacity and Better Choices'. World Wild Fund for Nature. https://wwfeu.awsassets.panda.org/downloads/lpr_living_planet_report_2012.pdf.
- Milkoreit, M., J. Hodbod, J. Baggio, K. Benessaiah, R. Calderón-Contreras, J.F. Donges, J-D. Mathias, J.C. Rocha, M. Schoon, and S.E. Werners. 2018. 'Defining Tipping Points for Social-Ecological Systems Scholarship – An Interdisciplinary Literature Review.' *Environmental Research Letters* 13(3): 033005.
- Nayak, P.K., D. Armitage, and M. Andrachuk. 2016. 'Power and Politics of Social-Ecological Regime Shifts in the Chilika Lagoon, India and Tam Giang Lagoon, Vietnam.' *Regional Environmental Change* 16(2): 325–339.
- O'Connell, D., B. Walker, N. Abel, N. Grigg, A. Cowie, and G. Durón. 2015. 'An Introduction to the Resilience, Adaptation Pathways and Transformation Assessment (RAPTA) Framework.' Washington, DC: United Nations Scientific and Technical Advisory Panel. www.stapgef.org/sites/default/files/documents/Summary_RAPTA.pdf-July-16.pdf.
- Orach, K., and M. Schlüter. 2016. 'Uncovering the Political Dimension of Social-Ecological Systems: Contributions from Policy Process Frameworks.' *Global Environmental Change* 40: 13–25.
- Ostrom, E. 2009. 'A General Framework for Analyzing Sustainability of Social-Ecological Systems.' *Science* 325(5939): 419–422.
- Pathways Network. 2018. 'T-Labs: A Practical Guide – Using Transformation Labs (T-Labs) for Innovation in Social-Ecological Systems.' Brighton: STEPS Centre.
- Pereira, L.M., T. Karpouzoglou, N. Frantzeskaki, and P. Olsson. 2018. 'Designing Transformative Spaces for Sustainability in Social-Ecological Systems.' *Ecology and Society* 23(4): 32.
- Peterson, G.D. 2005. 'Ecological Management: Control, Uncertainty, and Understanding.' In *Ecological Paradigms Lost: Routes of Theory Change*, edited by K. Cuddington and B.E. Beisner, 371–391. Amsterdam: Elsevier.
- Petursdottir, T., O. Arnalds, S. Baker, L. Montanarella, and Á.L. Aradóttir. 2013. 'A Social-Ecological System Approach to Analyze Stakeholders' Interactions within a Large-Scale Rangeland Restoration Program.' *Ecology and Society* 18(2): 29.
- Pohl, C., and G.H. Hadorn. 2007. *Principles for Designing Transdisciplinary Research*. Munich: Oekom.
- Prell, C., K. Hubacek, and M. Reed. 2009. 'Stakeholder Analysis and Social Network Analysis in Natural Resource Management.' *Society and Natural Resources* 22(6): 501–518.
- Puri, R.K. 2011. 'Documenting Local Environmental Knowledge and Change.' In *Conducting Research in Conservation: Social Science Methods and Practice*, edited by H.S. Newing, 146–169.
- Ramankutty, N., and J.A. Foley. 1999. 'Estimating Historical Changes in Global Land Cover: Crops-lands from 1700 to 1992.' *Global Biogeochemical Cycles* 13(4): 997–1027.
- Reed, M.S., A. Graves, N. Dandy, H. Posthumus, K. Hubacek, J. Morris, C. Prell, C.H. Quinn, and L.C. Stringer. 2009. 'Who's in and Why? A Typology of Stakeholder Analysis Methods for Natural Resource Management.' *Journal of Environmental Management* 90(5): 1933–1949.
- Resilience Alliance. 2010. 'Assessing Resilience in Social-Ecological Systems: Workbook for Practitioners 2.0.' Resilience Alliance. www.resalliance.org/resilience-assessment.
- Rodríguez, L.C., U. Pascual, and H.M. Niemeyer. 2006. 'Local Identification and Valuation of Ecosystem Goods and Services from Opuntia Scrublands of Ayacucho, Peru.' *Ecological Economics* 57(1): 30–44.
- Roth, W-M., L. Radford, and L. LaCroix. 2012. 'Working with Cultural-Historical Activity Theory.' In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* 13(2): Art. 23. <http://nbn-resolving.de/urn:nbn:de:0114-fqs1202232>.
- SANBI and UNEP-WCMC. 2016. 'Mapping Biodiversity Priorities: A Practical, Science-based Approach to National Biodiversity Assessment and Prioritisation to Inform Strategy and Action Planning.' Cambridge: UNEP-WCMC. <http://biodiversityadvisor.sanbi.org/wp-content/uploads/2016/06/Mapping-Biodiversity-Priorities-WEB.pdf>.
- Scholes, R.J., B. Reyers, R. Biggs, M.J. Spierenburg, and A. Duriappah. 2013. 'Multi-Scale and Cross-Scale Assessments of Social-Ecological Systems and their Ecosystem Services.' *Current Opinion in Environmental Sustainability* 5(1): 16–25.
- Schoon, M.L., M.D. Robards, K. Brown, N. Engle, C.L. Meek, and R. Biggs. 2015. 'Politics and the Resilience of Ecosystem Services.' In *Principles for Building Resilience: Sustaining Ecosystem Services in Social-Ecological Systems*, edited by R. Biggs, M. Schlüter, and M.L. Schoon, 32–49. Cambridge: Cambridge University Press.

- Schultz, L., C. Folke, and P. Olsson. 2007. 'Enhancing Ecosystem Management through Social-Ecological Inventories: Lessons from Kristianstads Vattenrike, Sweden.' *Environmental Conservation* 34(2): 140–152.
- Schultz, L., R. Plummer, and S. Purdy. 2011. 'Applying a Social-Ecological Inventory: A Workbook for Finding Key Actors and Engaging Them.' www.stockholmresilience.org/publications/artiklar/2011-06-07-applying-a-social-ecological-inventory-a-workbook-for-finding-key-actors-and-engaging-them.html.
- Sheil, D., and N. Liswanti. 2006. 'Scoring the Importance of Tropical Forest Landscapes with Local People: Patterns and Insights.' *Environmental Management* 38(1): 126–136.
- Smith, A., and A. Stirling. 2010. 'The Politics of Social-Ecological Resilience and Sustainable Socio-Technical Transitions.' *Ecology and Society* 15(1): 11.
- Stringer, L.C., A.J. Dougill, E. Fraser, K. Hubacek, C. Prell, and M.S. Reed. 2006. 'Unpacking "Participation" in the Adaptive Management of Social-Ecological Systems: A Critical Review.' *Ecology and Society* 11(2): 39.
- Tengö, M., E.S. Brondizio, T. Elmqvist, P. Malmer, and M. Spierenburg. 2014. 'Connecting Diverse Knowledge Systems for Enhanced Ecosystem Governance: The Multiple Evidence Base Approach.' *Ambio* 43(5): 579–591.
- Thompson-Hall, M., E.R. Carr, and U. Pascual. 2016. 'Enhancing and Expanding Intersectional Research for Climate Change Adaptation in Agrarian Settings.' *Ambio* 45(3): 373–382.
- Van Kerkhoff, L., and L. Lebel. 2006. Linking Knowledge and Action for Sustainable Development. *Annual Review of Environment and Resources*, 31: 445–477.
- Wali, A., D. Alvira, P. Tallman, A. Ravikumar, and M. Macedo. 2017. 'A New Approach to Conservation: Using Community Empowerment for Sustainable Well-Being.' *Ecology and Society* 22(4): 6.
- Walker, B., C.S. Holling, S.R. Carpenter, and A. Kinzig. 2004. 'Resilience, Adaptability and Transformability in Social-Ecological Systems.' *Ecology and Society* 9(2): 5.
- Watson, C.W. 2010. 'Ethical Issues in Research.' In *Conducting Research in Conservation: Social Science Methods and Practice*, edited by H. Newing. Abingdon: Routledge.
- Wulder, M.A., R.J. Hall, N.C. Coops, and S.E. Franklin. 2004. 'High Spatial Resolution Remotely Sensed Data for Ecosystem Characterization.' *BioScience* 54(6): 511–521.
- Zheng, Y., A. Byg, B.J. Thorsen, and N. Strange. 2014. A Temporal Dimension of Household Vulnerability in Three Rural Communities in Lijiang, China. *Human Ecology* 42(2): 283–295.