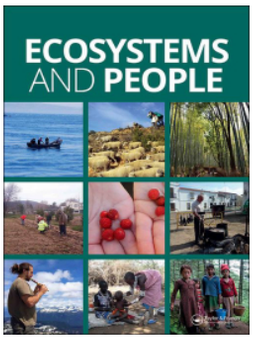

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RESEARCH

Learning from sticky variables in cross-case analyses of collaboration in social-ecological systems

Aireona Bonnie Raschke [a,b], Jessica Cockburn [c], Paúl Cisneros [d], Anahí Ocampo-Melgar [e], Michael Schoon[f], Candice Carr Kelman [f] and Jaishri Srinivasan[f]

[a]Central Arizona Conservation Alliance, Desert Botanical Garden, Phoenix, AZ, USA; [b]Center for Collaborative Conservation, Colorado State University, Fort Collins, CO, USA; [c]Department of Environmental Science, Rhodes University, Makhanda, South Africa; [d]Escuela de Gobierno y Administración Pública, Instituto de Altos Estudios Nacionales, Quito, Ecuador; [e]Facultad de Ciencias Forestales y de la Conservación de la Naturaleza, Universidad de Chile, Santiago, Chile; [f]School of Sustainability, Arizona State University, Tempe, AZ, USA

ABSTRACT

The importance of collaborative approaches to governing social-ecological systems (SES) towards more transformative outcomes is now widely acknowledged. Theoretical and methodological frameworks to enable such collaborations are being developed across a range of disciplines. Transdisciplinary approaches are emerging as a key enabler of potentially transformative collaborations in SES, particularly where these are characterized by 'multiple multiples' (e.g. multiple scales, knowledge systems, etc.). A typical approach to studying complex collaborative initiatives across a range of contexts is comparative case study research, often relying on researchers embedded in cases. In this approach, qualitative case studies are coded using predetermined variables (based on ecological, social, and social-ecological features of cases) to enable comparison and cross-case analysis. In our experience, the process of coding qualitative cases into a quantitative analysis framework can be hampered by what we term 'sticky variables', i.e. variables which are difficult to code for reasons related to aspects of the intrinsic complexity of social-ecological systems. Based on cases from a range of geographic locations across the Global North and South, we identify sticky variables, and elucidate the reasons for their 'stickiness'. We propose several ways of working with and learning from sticky variables, and we reflect on theoretical, methodological and reflexive aspects of transdisciplinary research on collaborations. Moreover, we suggest that sticky variables might be 'flags' for interesting underlying factors that influence collaboration. We conclude by drawing out recommendations for researchers and practitioners confronted with the complexities and nuances of collaborations in social-ecological systems around the world.

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1. Introduction

1.1. Importance of collaborative management and governance of SESs

The sustainable management of social-ecological systems (SES) often requires collaborations, including between groups with divergent interests and expertise, with effective collaborative processes moderating conflict and potentially leading to more inclusive and informed decision-making (Wondolleck and Yaffee 2000; Connick and Innes 2003). We define collaborative governance as collective decision-making (not necessarily including government), and management as the execution of governance objectives or implementation of decisions. Collaborative governance often involves nested and overlapping, polycentric institutional arrangements, thus enabling quasi-autonomous decision-making linking multiple jurisdictional scales (Olsson et al. 2006). Collaborative governance of natural resources emerged as a strategy for generating innovative, demand-driven solutions in response to complexities of landscape-scale conservation (Ansell and Gash 2008; Sørensen and Torfing 2011; Ansell 2022; Gash 2022).

1.2. Studying and supporting collaborations: typical approaches and challenges

Much research on collaboration in the governance of SES has been either theoretical or case-based to date. Over the past two decades, researchers began moving to case comparisons (e.g. Wondolleck and Yaffee 2000; Armitage et al. 2010), although much of the work remains qualitative in nature. However, purely qualitative cross-case comparison has limits in the number of cases that can be compared and the number of independent variables that can be studied. Moving beyond the rich, thick data of qualitative research and small-N studies requires a shift in data collection to more quantitative approaches that build

CONTACT Aireona Bonnie Raschke araschke@colostate.edu
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upon theoretical bases. As the chasm between some quantitative and qualitative researchers demonstrates, this is neither simple nor straightforward. This manuscript has evolved out of a research program that studies collaborative governance and management of SES, and the challenges of moving from qualitative to quantitative research.

Drawing on previous meta-analyses of collaborations (Plummer and Armitage 2007; Ansell and Gash 2008; Armitage et al. 2009), we identified a set of variables seen to influence the outcomes of collaborative projects (Carr Carr Kelman et al. under review). From this we constructed a framework that aggregated these variables into three types – context, mechanism, and outcome variables (Cockburn et al. 2020). We also devised a coding manual and training program (Schoon et al. 2020). However, as more researchers began to code their case studies, a number of variables recurrently raised issues for coding.

1.3. Sticky variables: what they are and why they are of interest

'Sticky' variables are those variables within the transdisciplinary framework represented by the coding manual (see Figure 1) for which coders struggled to definitively categorize and describe due to differing interpretations of and/or idiosyncrasies within each case (as opposed to different interpretations of the questions). As elaborated in the discussion, these variables might be 'Sticky' due to their fluidity over time, and/or due to variations in related characteristics across different scales (e.g. spatial, institutional). They may also represent variables that are ill suited to quantitative and/or categorical analysis.

Sticky variables were of interest to our team of collaboration researchers and practitioners because they represent essential but particularly dynamic elements of collaborative efforts for which there is potential, through interdisciplinary synthesis, to advance our understanding of collaboration.

Despite the depth of knowledge represented by academic literature, there are challenges that limit their applicability to the design, evaluation, and adaptation of on-the-ground projects and management. For practitioners, there is a lack of accessible information on complex variables that can impact their collaborations, and for which practitioners are seeking guidance and knowledge-sharing (Gould et al. 2019). Our investigation of sticky variables can assist in addressing some of these implementation barriers and make existing academic, collaborative knowledge more applicable.

Our paper identifies key sticky variables related to assessing collaboration, explores the underlying reasons for their apparent complexity, and posits both theoretical and practical applications of this exploration. The following sections outline the mixed-methodology applied, describe the variables identified through the process as 'sticky' and the proposed reasons for this, and then discusses the implications of the complex characteristics of these variables on collaboration research and practice.

2. Methodology and methods

2.1. Overall approach

Our study took place within an international collaboration of scholar-practitioners in the *Collaborative Management and Governance Working Group* of the

Coding elements		
Context	**Mechanisms**	**Outcome**
• Collaboration status • Formality of collaboration • Ecosystem scale • Group size • Users rights • Property rights • Diversity of objectives • Collaboration goals • Governance of collaboration • Governance of the resource • Resource type • Resource dependence • History of collaboration • History of colonialism • Funding • Facilitation • Complexity • Power asimmetry • Culture type	• User boundaries • Resource boundaries • Rules fit with ecology • Rules fit with local culture • Equity • Collective choice arrangements • Monitoring of resource • Monitoring of monitors • Graudated sanctions • Conflict resolution • Rights to organize • Nested enterprises • Adaptability/variety • Social learning • Shared vision • Leadership • Capacity • Knowledge-building • Prior networks • Face to face communication • Trust & social capital	• Collaboration objective • Environmental outocmes • Social, politica or economic • Collaborative process

Figure 1. Variables included in the collaborative natural resource codebook.

Programme on Ecosystem Change and Society (PECS: www.pecs-science.org). We build on on-going work to develop empirical and theoretical (e.g. Aburto et al. 2017; Hill et al. 2021; Schoon et al. 2021), methodological (e.g. Cockburn et al. 2020; Schoon et al. 2020), and practical (Carr Kelman et al. 2018) contributions to research, policy and practice for collaborative management and governance in SES. A focus of this group is to explore the role of social science concepts and theories in supporting transformative collaborative processes and strengthening transdisciplinary research. In addition, we are interested in uncovering how multiple cases of collaboration, transdisciplinary research, and learning can be analyzed and compared using these, and similar, social science concepts (Lotz-Sisitka et al. Forthcoming).

The overall methodological approach of the group, which also informed the approach adopted here, is comparative case study research, a methodology widely used to study SES (Pahl-Wostl et al. 2021). This is framed within a complexity worldview, in which natural resource management and governance is embedded in complex SES that are open, dynamic, and adaptive (Preiser et al. 2018). In this study, we utilized a qualitative, deliberative approach to generate shared understanding on sticky variables based on the in-depth experience of the co-authors (Norström et al. 2020; Chambers et al. 2021).

Below we introduce the codebook which forms the basis of the on-going comparative case study research of the broader working group, then we explore our cases (Table 1), and we outline the stepwise process we took to identify and analyze the sticky variables.

2.2. Introduction to the codebook

The coding manual (or codebook) was collaboratively developed in 2017–2020 (with ongoing updates and adjustments), building upon a workshop held at the November 2017 PECS Conference in Oaxaca, Mexico. The purpose of the manual is to assess and compare collaborative natural resource or SES governance and management projects across the world. This macro approach is meant to enable metastudies of SES governance, and surface variables that most affect outcomes.

Currently, various disciplines approach the subject of collaborative governance of SESs using a variety of heterogeneous criteria and frameworks, making case-study comparisons difficult for those conducting meta-studies. Our manual aims to bridge many of these approaches by including variables for context, rule-based and process-oriented mechanisms, and outcomes. It is based on an interdisciplinary systematic literature review, which identified many of the variables present in the manual (Carr Kelman et al. under review).

Our manual has also undergone multiple revisions over 5 years and is now in version 10. It is available online as a PDF and we have created an online survey for data entry (see supplemental materials). It utilizes the basic structure of 'Context-Mechanisms-Outcomes' (CMO) used in realist evaluation methodology (Pawson and Tilley 1997; Salter and Kothari 2014), such that it can develop an understanding of 'What works, for whom, in what circumstances and why?' This is useful in explaining the successes and failures of collaborative management and governance (Cockburn et al. 2020). We adopt a wide view of what constitutes collaborative efforts, only requiring that they involve 3+ partners and some form of ecological system (Schoon et al. 2020).

2.3. Introduction to our cases

The empirical, place-based cases of collaboration which we drew on are located across a range of geographic contexts spanning four countries (Table 1). They are characterized by a diversity of resources and ecosystems, diverse stakeholders, a range of collaborative governance approaches and organizational structures (from distributed and bottom-up, to hierarchical or top-down), and work towards different visions and objectives. Thus, most of our cases are characterized by 'multiple multiples' and can be considered examples of multifaceted collaborative initiatives (Poteete 2012; Cockburn et al. 2018, 2020). This means that inter- and transdisciplinary research approaches are needed to effectively study these cases, along with a better understanding of the way in which a range of social science concepts and theories can be applied and interrogated to understand the complex social processes taking place (Lotz-Sisitka et al. In Review).

2.4. Stepwise process of identifying and reflecting on sticky variables

This study took a 4-step approach which was implemented through a series of online working sessions carried out over the course of a year, as follows:

- **Step 1: Identifying sticky variables based on individual cases**: Our team assessed all of the collaborative variables identified in the codebook for stickiness. This was done via expert assessment of the variables as they were represented by the cases outlined in Table 1. Our team has particular expertise in all of these cases, either as researchers or leading members of the collaborations. We collated and shared our individual assessments via Google Sheets.

Table 1. Overview of cases on which the analysis of sticky variables was based.

Case name and country	Brief case description: geographic location, key resources/ characteristics of the SES, nature and purpose of collaboration, etc. (Please also note any references/publications for the case/context which could be cited).	Which variables were particularly 'sticky' for this case?
1. Tsitsa Project (South Africa)	The Tsitsa Project is an integrated landscape management initiative located in the rural Eastern Cape of South Africa (2014–2021). The vision of the collaboration is to 'to support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem Services'. The landscape is characterized primarily by grassland vegetation, and is highly erodible, making land degradation a key challenge. The collaboration was coordinated by Rhodes University, and included a range of partners from local communities, government, NGOs, and research institutions (Cockburn et al. 2018).	• Group Size • User rights • Governance of the collaboration • Funding • Culture type • User boundaries • Rules fit with ecology • Rights to organize • Adaptability/variety of institutions • Social learning • Shared vision and long-term commitment • Prior networks • Trust and social capital • Collaboration objective • Environmental outcomes • Social, political or economic outcomes
2. Central Arizona Conservation Alliance (CAZCA) (United States of America)	CAZCA is located in Maricopa County, Arizona, USA and focuses on the urbanizing Sonoran Desert. CAZCA was formed to support collaboration around habitat connectivity, habitat restoration, and public outreach in Central Arizona due to rapid urban development in the region.	• History of collaboration or conflict • Power asymmetry • Adaptability/variety of institutions • Social learning • Knowledge-building • Trust and social capital
3. Machángara watershed council (MWC) (Ecuador)	MWC is a cross-sectoral and multi-level voluntary organization formed by representatives of the municipality of Cuenca, the water utility ETAPA, the Machangara river water board (mostly small-scale farmers), the public electric utility ELECAUSTRO, the Ministry of the Environment and Water, the Ministry of Agriculture, the University of Cuenca and the Provincial government of Azuay. Its objective is to contribute to the sustainable management of natural resources in the Machangara watershed which is one of the main sources of water for the city of Cuenca and its vicinity. The landscape is composed of paramo and tropical forests, and most of its area is protected under the national and local biodiversity conservation systems (Cisneros 2019).	• Rules fit with local culture • Adaptability/variety of institutions
4. Limarí Surveillance Boards (SB) Water Users' Organization (Chile)	The Limarí SB is a formal organization formed by water rights shareholders (mostly farmers), who own a certain quota of a river flow. The organization is formed by representatives of smaller irrigation organizations, and has the role of supervising water shares distribution, maintaining the river channel and monitoring members' use of water. It is formally established following the provisions of the Water Code (article 263) and has statutes approved by the Ministry of Public Work. This particular organization is also part of another group managing the Paloma Dam System, largest dam in Chile.	• User rights • User boundaries • Adaptability/variety of institutions • Trust and social capital.
5. White Mountains Stewardship Project, Arizona (USA)	WMSP was a formal collaborative governance program focused on restoring forest ecosystems in eastern Arizona within the Apache-Sitgreaves National Forest to reduce the threats of wildfire (especially in the wildland urban interface zones) by thinning 150,000 acres of federally managed forests between 2004–2014 (Abrams and Burns 2007). A century of fire suppression, logging and grazing has created overly dense forests that also endanger communities nearby. These unhealthy forests are of low economic and ecological value, containing 300–3000 small-diameter trees per acre rather than 20–60 healthy trees per acre (Sitko and Hurteau 2010).	• User rights • Property rights • Governance of the resource • Resource dependence • Power asymmetry • Culture type • User boundaries • Rules fit with ecology • Rules fit with local culture • Congruence of benefits and costs • Collective choice arrangements • Graduated sanctions • Conflict resolution • Environmental outcomes
6. Heber Wild Horse Territory, Arizona (USA)	The Heber Wild Horse Territory (HWHT) is an area of the Apache-Sitgreaves National Forests, covering 19,700 acres within the Black Mesa Ranger District, created in 1971 under the Wild Free-Roaming Horses and Burro Act. Following the 2002 Rodeo-Chediski fire, which destroyed miles of fencing, there was a population boom of horses in and around the territory, and a roundup was proposed by the Forest Service. Litigation stopped the roundup and a court stipulation in 2007 required the Forest Service to create a management plan for the territory. Due to the controversial nature of wild horse management in the western USA, the Forest Service asked that an independent collaborative working group be convened by Arizona State University to collaboratively create a management plan. Members of this group were selected to represent a broad variety of interests in the horses and the wild horse territory. The working group met regularly between August 2017 and October 2018 to develop recommendations on a management plan for the HWHT.	• Resource type • Resource boundaries • Shared-vision and long-term commitment • Collaboration objective • Environmental outcomes • Social, political and economic outcomes • Collaborative process

(*Continued*)

Table 1. (Continued).

Case name and country	Brief case description: geographic location, key resources/ characteristics of the SES, nature and purpose of collaboration, etc. (Please also note any references/publications for the case/context which could be cited).	Which variables were particularly 'sticky' for this case?
7. Upper Colorado River Endangered Fish Recovery Program (UCR-EFRP) (United States of America)	The UCR-EFRP is a program to mitigate water use in the Upper Colorado River Basin and conserve four species of native fish that are endangered under the Endangered Species Act. The program undertakes aggressive invasive species management, fish passage construction and native fish stocking, floodplain reconstruction, coordinated reservoir reoperation and instream flow management for native fish propagation as well as public awareness campaigns.	• User rights • Property rights • Rules fit with local culture • Collaboration objective

- **Step 2: Identifying top/common sticky variables across cases/researchers**: We identified the most common sticky variables as those that were identified as sticky by three or more researchers in the 7-member team.
- **Step 3: Exploring 'reasons for stickiness' within and across cases**: Based on the top/common sticky variables, and drawing on our knowledge of our particular cases, as well as the notes made in the Google Sheet during Step One, we discussed why these variables were sticky. We went through a three-step, collaborative process to explore the reasons for stickiness: (1) brainstorming and idea production, (2) grouping of reasons into overarching themes, and (3) refinement of ideas around these underlying reasons. For this exercise we made use of Google Jamboard.
- **Step 4: Reflecting on the implications of the sticky variables and the reasons for stickiness**: During several sessions, we considered what the findings from Step 1–3 mean for theoretical, methodological and reflexive aspects of studying and supporting collaborations in social-ecological systems. This entailed drawing on our own experiences and the literature to consider critically what to do with the findings of our analysis.

3. Results

We used the stepwise process described above to identify eight common sticky variables, and delineate reasons for their stickiness. Both will be discussed in the following section.

3.1. Which variables are sticky

3.1.1. User rights

This variable refers to the type of access rights people have to the resource. Schlager and Ostrom (1992) identify at least 4 'bundles of rights' that determine the extent of access one has to a common resource. Based on this typology, the coding manual asks coders to select all relevant categories that describe the participants of the collaboration: owners, proprietors, claimants, and authorized users Figure 2.

User rights were identified as a sticky variable in three of the study cases because these collaborations include different types of participants, some of which may own rights, but others only hold legitimate interests, for example, researchers and NGOs. This was the case for the Tsitsa Project, the White Mountain Stewardship project and the Upper Colorado Endangered Fish Recovery Program (UCREFRP). In addition, the variable doesn't sufficiently capture users outside of the collaborative effort, who may or may not be authorized users, such for the Tsitsa Project, where unauthorized users played an important role. In the UCREFRP case, while there was a well-defined legal landscape for water use, any changes in water use requires water rights holders' to justify adjustments using a detailed historical use analysis, and this often results in significant reductions of their annual water rights.

For the Limari SB in Chile, important nuances about user rights are not captured by the variable. Chilean water users' organizations are formed only by shareholders of water rights (*derechos aprovechamiento de agua* or DAA in Spanish), who own a certain quota of river flow, which gives them proportional voting rights. They can extract the resource granted and register it in the Public Water Registry (CPA) of the General Water

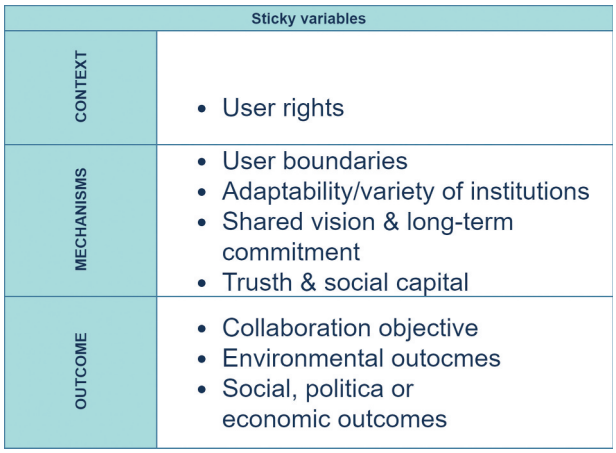

Figure 2. Variables included in the coding manual identified as 'sticky' by at least 3 of the cases.

Directorate (DGA), sell or lease it, use it, transfer the right to a different sub-basin, and prevent third parties from making improper use of unregistered waters. Although this fits the 'owner' type of access (Schlager and Ostrom 1992), there are limits to this ownership that makes the coding sticky, such as in cases of water scarcity. For example, the National Water Authority has the ability to limit their use (Shortage Decrees) and in some cases, buy some DAA for conservation. Governmental limits to private water rights are currently changing after a reform to the Water Code.

Collaborations in more complex systems with a diversity of resources and resource users are tending to become more common (Cockburn et al. 2020). In these cases, variables such as user rights (and also others, such as resource boundaries, see Section 3.1.4), which are fairly straightforward in single-resource or single-user systems, become more difficult to code, i.e. they become more sticky. In such systems, 'patchiness' also increases, which we discuss further in Section 3.2.2.

3.1.2. Institutional adaptability/variety/flexibility

Governance systems should be built for adaptation and changes in the SES. Approaches may include adaptable institutional design, an overlapping, nested polycentric variety of institutional types, or engaging in iterative risk management (Dietz et al. 2003; Olsson et al. 2006; Gruber 2010; Stern 2011). A prepared governance system designed to cope with changes can respond quickly, reduce the impact of unforeseen change, and allow for an effective response (Young 2002; Olsson et al. 2006; Armitage et al. 2009; Plummer et al. 2012).

This variable was found sticky in four of our study cases. The difficulties in coding this variable were related to i) the strategic choices made by collaborators to adapt to their changing contexts, and ii) the diversity of situations within the collaborative group. Regarding strategic choices, the MWC case (Ecuador) showed flexibility and adaptability in responding to emerging challenges such as national policy changes that constrain participation by NGOs. However, the collaboration avoided other adaptations to maintain internal cohesion and restrict conflicts to manageable levels.

Organizations may also be framed by rules that emphasize adaptability, but due to a variety of reasons (including financial and capacity limitations) these are not implemented. For CAZCA, limited resources, as well as complex social and environmental objectives, made adaptation capabilities variable. In some cases, adaptation was necessary but grant timelines, partner objectives, and overallocated staff prevented timely adjustments. Furthermore, at times CAZCA objectives conflicted with one another due to contextual realities, and this created a necessity for strategic allocation of limited resources to adaptation only for prioritized objectives.

Other rules that are not about flexibility, can lead to more adaptive governance than expected. The incongruence between theory and practice is also related to the second factor which is the diversity of situations that are found in these collaborative groups. In the Tsitsa Project (SA), the larger group is designed for flexible management, even though the organizations within are not necessarily adaptive. That situation was also found in Chile and Ecuador, as there are dissimilar situations in each layer of the organization that may hinder attempts at adaptive governance in unison. For example, the Surveillance Boards in Chile include representatives from a diversity of smaller water organizations with different socio-economic contexts that impact their capacity to change or innovate (i.e. when drought conditions demand stricter monitoring of water distribution, not all organizations have the technology to adopt those changes).

3.1.3. Trust and social capital

Trust among stakeholders has repeatedly been deemed a crucial indicator for the effectiveness of a collaborative effort, as well as a basis for adaptation (Ostrom 1990; Young 2002; Dietz et al. 2003; Olsson et al. 2006; Ansell and Gash 2008; Armitage et al. 2009; Ostrom 2009; Cox et al. 2010; Gruber 2010; Ostrom and Cox 2010; Stern 2011).

This crucial indicator for successful collaboration was identified as one of the stickiest variables to code in three of the cases. Trust takes a long time to build and an instant to break. Mixed responses from different actors within the collaboration, and different assessments depending on the time frame defined, made this variable patchy over time and across actors.

Overall, our analysis showed that although there is sometimes a degree of distrust regarding decisions that are made in a group, collaborative initiatives continue, probably due to a higher mutual interest in the resource being managed jointly or because of other interests (monitoring behaviors, organizational survival, etc). Sometimes the collaboration was seen as a way to influence decisions and counterbalance the power of other actors. Knowledge of historic trust-breaking activities, variable experiences among partners, and ongoing developments among members of the collaborations often created a shifting landscape of trust and social capital among partners, which was at times beneficial to the collaboration and at other times threatened its ongoing existence.

3.1.4. User boundary/collaborative boundary

Based on Ostrom's (1990) first design principle (Cox et al. 2010), this variable concerns the rules or social

norms that specify who is allowed to participate in the collaboration. It was coded as sticky in two of the study cases where findings show that i) there is often a blurred boundary between those who use the resource and those that participate in the collaboration, meaning there may be more users than are officially part of the collaboration, and ii) those who participate in the collaboration hold different levels of influence.

In the Tsita case, only some users are part of the collaboration as this is voluntary and somewhat misaligned with the existing resource boundaries. In the Chilean Watershed users' organizations, these organizations are not only misaligned with the basin, but also there are varied levels of decision-making power related to the number of water shares, which affects the fairness and equity in participation.

Even though the variable itself is not meant to catch this particular aspect of participation, the coding exercise reveals that evaluating who is included in the collaboration is indirectly related with the extent (whether boundaries match the social-ecological system) and quality of participation (how decisions are made by those who participate).

3.1.5. Shared vision and long term-commitment

Long-term commitment to the shared goals of the collaboration has repeatedly been identified as a core component of collaborative natural resource governance (Wondolleck and Yaffee 2000; Armitage et al. 2009). This includes mobilizing broad support for change among stakeholders, and sharing power and responsibility among those involved (Olsson et al. 2006; Ansell and Gash 2008, Gruber 2010). Nonetheless, in at least two of the cases where a shared vision for the collaboration existed, there was a situation of dissimilar agreement among participants.

In the Tisita case, there were stakeholders that were not part of the shared vision's development which led to different degrees of commitment. Similar 'patchiness' was found in the Heber Wild Horse case, where there is a diversity of informal and formal commitments within the organization. Most members of the collaborative worked toward a set of common goals, but a few worked from within to sabotage those efforts. In contrast, the MWC and the White Mountains case show that the continuity of facilitation throughout the collaborative experience was perceived as a key factor to sustaining a shared vision and long-term commitment despite changing regulations and emerging management challenges.

3.1.6. Collaboration objectives

This and the next two variables are some of the most important in the coding manual, because they are focused on assessing the outcomes of the collaboration. It makes sense that it would be easy to get stuck in identifying whether the collaboration has achieved its core objectives, as written objectives may vary from implemented ones, and implemented ones may not be completed, measured, or measurable.

In some cases there were several objectives, each achieved to different degrees (e.g. Tsitsa Project), while in other cases, the official objectives were met, but there were differences between the official and unofficial goals (e.g. Heber Horses). The MWC shows that practices for measuring progress towards objectives is also another source of stickiness for this variable. Participants privilege certain objectives and indicators as a function of the resources they have (e.g. information, time, money, technical capacity). Also, ensuring the achievement of procedural objectives such as support for yearly plans could lead to choosing favorable indicators to justify the relevance of the collaboration (Leach and Sabatier 2005).

3.1.7. Environmental outcomes

Besides the usual challenge of disentangling the complex cause-effect connections for ecological results, environmental outcomes of collaboration were sticky to code due to i) the extended time that environmental impacts require to manifest, ii) the possibility in which rapid ecological dynamics may change and impact ongoing initiatives, and iii) the need to supplement actor's perception with long-term ecological measurements. For the Heber wild horse case, results were mixed, and were interpreted differently by group members. Similarly, in the White Mountains Stewardship project, the treatment of thinning dense forests proved to be effective at stopping wildfires, but the project was not able to accomplish its acreage goals, partly due to US Forest Service rules regarding hiring contractors.

In the Tsitsa case, localized soil restoration initiatives are showing tangible environmental outcomes (e.g. improved vegetation cover, reduced run-off and sedimentation), but the long-term sustainability of these outcomes is in question since they are dependent on external funding, knowledge, and capacity. Similarly, the large scale of land degradation in the catchment call into question the feasibility of achieving these environmental outcomes at scale across the catchment as a whole.

This is especially difficult to address given the possibility of social-ecological disruption and inefficiencies resulting from mismatches between social organization and environmental processes that may go beyond the collaborative initiative, or for which the collaboration is not appropriately designed to address (Cumming et al. 2006; Sayles and Baggio 2017). These may include internal (process related) variables or external (actor or issue related) variables of the decision-making process (Newig and Moss 2017).

Another thorny issue which has been flagged in the collaborative management literature (Coglianese 2003; Koontz and Thomas 2006) is the need to supplement the actor's perception of environmental conditions with measurements conducted by external monitors. This helps reduce potential biased assessments of environmental performance.

3.1.8. Socio-economic outcomes

This variable asks whether local social conditions improved as a result of the collaboration. Socio-economic outcomes of collaborations can be tricky to generalize, as the social, political or economic impacts of projects exhibit different dynamics that are not necessarily experienced together. There are at least two reasons for this: i) they may be influenced by power dynamics outside the control of the group, and ii) they are often difficult to separate from their contexts (e.g. economic instability). The Heber case showed that although there may be individual economic gain associated with the collaboration, internal conflict increased.

In the Tsitsa case, a small number of people have benefited from direct employment and capacity development activities (Mtati 2020). However, this is short-term and funding dependent, and the number of beneficiaries is miniscule compared to the overall levels of unemployment and poverty across the catchment. This illustrates that questions of scale and long-term resourcing have a significant impact on potential positive outcomes of collaborations, making it difficult to code these outcomes with confidence.

One of the main mechanisms used in the MWC for the conservation of the paramo was international cooperation resources. For a few years, these resources were allocated by the national government to local communities through a public program of compensation for environmental services. However, the adoption of structural adjustment policies to deal with external debt froze those transfers, depriving small-scale farmers of alternatives for securing a predictable income and endangering the progress in local-wellbeing.

3.2. Reasons for stickiness

We recognize four common causes of stickiness – fluidity (dynamics over time), patchiness (variability at a given time), the human dimensions of a case, and the challenges of collecting and coding cases for metastudies (i.e. methodological reasons). These are often overlapping and share common elements.

3.2.1. Fluidity – dynamics over time

All the variables identified as sticky produce assessments of specific aspects of collaborative initiatives as snapshots in time. This may not be problematic for many slow-changing variables (e.g. user rights, user boundaries), but for other variables the coding exercise unveiled their intrinsic fluidity.

Trust and Social capital, a fragile asset of collaborations, can drastically change due to a variety of internal and external economic, political, interpersonal, and environmental factors impacting the context in which this variable operates, as well as the timeframe. For example, major events from a political crisis to a global pandemic can impact the process by which members of collaborative groups interact, changing strategic trajectories, increasing resource shortfalls, and undermining pre-existing relationships. Therefore, collaborations can be subject to abrupt changes that could deeply affect this variable, and it can be a challenge to assess whether trust increased as a result of the collaboration.

There are other biophysical-related variables that are fluid in time. Those variables that have short timescale dynamics may be difficult for static (snapshot) coding. Examples include the rapid growth and revegetation rates of alligator juniper in the Heber horse case.

3.2.2. Patchiness – variability in a singular time

Collaborations are usually a complex nest of hierarchical organizations, and/or representatives of groups in different socio-economic, environmental and legal situations (Wyborn and Bixler 2013). This organizational patchiness generates non-homogeneous experience of the *environmental and social outcomes*. For example, *users rights* and *institutional adaptability*, may result in very different responses depending on which members are assessing and their personal experience with that variable.

Different opinions within the organization also cause patchiness that makes it challenging to code variables such as *collaboration objectives* and *shared visions*, as the response will vary on which stakeholder or group is the focus of the analysis. Averaging the response may be simpler in some cases, but in others, underlying power asymmetries and access to decision-making may influence group opinions, which would then undermine the relevance of the average.

3.2.3. Human dimensions that relate to the substantive elements of the case

Collaboration involves variables that relate to how people feel about themselves and others, but these factors are often not openly communicated. These are crucial elements that are difficult to capture by regular methodological approaches in natural resources governance research, as they are also related to cognitive and even psychological aspects of those involved (Grothmann and Patt 2005). This

relates back to the issue of timeframe and exposure to the collaboration by the researcher, which could potentially grant access to some underlying feelings and perceptions if enough rapport is achieved. So, it is not only that *Trust and Social capital* is difficult to assess due to its fluidity and patchiness, but it is also not easily inferred without highly embedded and honest coders.

3.2.4. Challenges of collecting and coding cases for metastudies

Collaborations are chosen by researchers for a variety of reasons, (Schlüter et al. 2022), and these general orientations along with the specific research questions being explored by the researcher influences the theoretical and methodological approaches used. Therefore, different approaches may influence the way a variable is understood, assessed, and coded (Simon and Schiemer 2015). The amount of information that any coder has on a case will also impact the quality of their answers. In cases where coders lack sufficient data, this could result in a less robust assessment of a variable, creating stickiness. Untangling this is problematic as we lack a measurement of the degree to which any coder has sufficient data.

There are also other methodological reasons why a coder may find it difficult to code a variable relating to the time of exposure to the case. Some coders had been studying or participating in their cases for years, which may allow a more complete picture of the collaborative dynamics. Averaging responses to any variable may be easier when exposure has been sustained, but that is often not the case for most SES research, especially when diverse stakeholders have different power, knowledge and interests (Simon and Schiemer 2015). Alternatively, deep familiarity or involvement in a case study can also make one's understanding so nuanced that coding becomes challenging.

Finally, the resources utilized to gather information on a case can influence the difficulty of coding. Although researchers strive for triangulation of data, resource constraints often lead to using some sources more intensely. For example, relying on public documents or standardized questionnaires to understand the history of conflict within a collaboration may blur issues related to the informal dynamics of building trust and social capital. For the purpose of this paper, each case study was done independently and methods differ slightly, although all research was qualitative.

4. Discussion

4.1. What to do about sticky variables?

Some of the sticky variables suggest that more theoretical and methodological work is required to adequately understand and measure critical mechanisms of collaborations. Important syntheses have been conducted in this regard, with factors that support adaptive institutions identified by Koontz et al. (2015) and on trust by Leach et al. (2005). However, a thorough review of how critical elements such as trust and institutional adaptability have been defined and operationalized seems to be required to further specify criteria for their use in future research and practice.

A subset of sticky variables suggests limitations on the theories underpinning the coding book. Limitations are of two types: scope and linearity. The context variable *user rights* is an example of the first limitation. The current variable is based on the *bundles of rights* proposed by Schlager and Ostrom (1992). However, the resulting classification of the types of access (authorized users, owners, claimants, proprietors) excludes actors without rights but that effectively extract or withdraw from a resource. The existence of this type of actor is essential to understand the informal dynamics of collaborations that constrain the capacity of enforcing rules or building agreements about resource use. A more complete assessment should include criteria beyond the formally assigned rights to consider the scope of use for those rights and their interactions with actors that collaborate based on legitimate interests.

On the other hand, the mechanism variables of *adaptability/variety/flexibility* and *shared visions and long-term commitment* suffer from a linear vision of collaboration. The first bundle of variables assumes that the mechanisms to respond to changing conditions will be either present or absent in the collaboration, while the case studies suggest there is patchiness, fluidity and structural holes. Collaborations operate as networks where some nodes are more closely interrelated, and where different types of relationships are built and maintained as a response to local and extra-local interactions among nodes, and between nodes and the environment. Changing conditions will affect interactions and components in different ways, resulting in nonlinear adaptation.

The implication of this patchiness is that even in well designed systems, the capacity to adapt to changing conditions cannot and probably should not be amenable to design. It will constitute an emergent property of the system given the capacity of the agents to make sense of the change and define the best means to manage it. In regards to maintaining long-term commitment in support of shared goals, what the case studies show is that such support is present with different intensities as the collaboration unfolds. Although participants express and maintain support for the shared goals, this support may be only active vis-à-vis external actors, such as in the process of collective lobbying. However, once collective goals have been achieved, support for collaboration may

shift back towards the missions of single organizations or individuals.

In our cases, as these were part of an international effort to analyze and compare collaboration patterns (Schoon et al. 2020), coding for variables was accompanied by a text box to allow evaluators to explain the reasons for their assessment. Nonetheless, this does not necessarily mean that stickiness was completely overcome, as it is simply a way to highlight the possibility that the coding may be temporal (i.e. the variable changes over a relatively short time), partial (i.e. the variable does not correspond to an homogeneous characteristic), or requires further study. In fact, we do not believe stickiness can always be solved, and it is an aspect that we must embrace when trying to study collaboration. However, stickiness can be addressed in the process of coding (see section 4.2).

4.2. How to overcome stickiness when coding

As researchers familiar with our case studies, it can be difficult to give a simple answer to a question that brings up many different interconnected aspects of collaboration, but it is possible to navigate stickiness when coding. Here we offer six ways to do so:

(1) Use the textbox to explain your answer. Exploring the qualitative details can help make a decision.
(2) Talk to others familiar with the case. Opening up a dialog about the question may help to clarify how a sticky variable should be coded.
(3) Review the definitions in the PDF version of the codebook, which is more comprehensive than the survey version, and sometimes go back to the theory via the references listed in the codebook to make sure you understand the variable sufficiently.
(4) Accept that your answer is a snapshot in time that could change in a future coding of the case.
(5) Remind yourself that reductive processes like coding are necessary for us to compare and learn from large numbers of cases, and that of course it has its drawbacks and trade-offs (and that one can complement this with more qualitative and in-depth case studies).
(6) Select the 'best possible answer' keeping in mind the above and knowing that even though it is possibly only partially correct, it contributes to growing our knowledge and understanding of collaboration.

4.3. Could sticky variables be 'flags' for underlying factors that influence collaboration?

Although contexts are active agents that enable or inhibit systemic agency (Cockburn 2021), most of the contextual variables in the cases under review were not coded as sticky. With the exception of user rights, the other 16 context variables were relatively easy to code. This finding suggests that fluidity and patchiness may affect some components of complex systems more than others. In these cases, the analysis of users rights is characterized by the difficulty of narrowing down the set of multiple-multiples (such as multiple types of stakeholders and rights holders) (Cockburn et al. 2020), and their interactions in one particular moment.

Four mechanism variables were coded as sticky. These sticky variables are affected by fluidity and patchiness in multiple ways which makes them perfect candidates for metastudies and longer term analysis to narrow down the ways they interact with other mechanisms, and contextual and outcome variables. In addition, these variables show the influence of human dynamics, and addressing this may require the integration of theoretical and methodological insights from psychology and cognitive sciences to the dominant approaches in SES theory. Several aspects of trust remain understudied in the contexts of collaborative resource management such as the interactions of trust, beliefs, behaviors, and social capital, that require longitudinal studies (Lewicki and Brinsfield 2012; Blumberg et al. 2015), and the role of trust (and mistrust) across different cultures. Recent theoretical insights derived from anthropological studies of the interactions between western and non-western systems of responsibility could help tackle these issues (Corsín Jiménez 2011).

Most of the outcome variables were identified as sticky (3 out 4). This is unsurprising considering that interactions within collaborative initiatives in complex systems (e.g. a multifunctional landscape with various resources) create multiple feedbacks with the context, mechanisms and other outcomes. As the ideas of fluidity, patchiness and non linearity suggest, these feedbacks are not immediate, nor do they affect all the components of a given system with the same frequency or intensity. It has been suggested that inter- and transdisciplinarity could help tackle this issue as it allows researchers to take stock of multiple relations within complex systems. However, the potential contribution of inter- and transdisciplinarity is contextual given that trade-offs exist between engaging with specific problem-solving processes and producing generalizable research (Simon and Schiemer 2015. Studying collaborative initiatives may be riddled with paradoxes and multiple interpretations that all attempts to grasp the complexity that open systems face.

4.4. Resulting adjustments to the codebook

In response to this project and other feedback, we edited the coding manual to capture the dimension of

time for trust and social capital. Rather than asking if trust and social capital increased over time as a result of the collaboration, we now have two questions, one that asks about trust levels before the collaboration began and one about trust levels at the end or current point of the collaboration. This allows for more variability in the answer, although trust levels may change due to events external to the collaboration itself.

To address the issues with the outcome variables being difficult to code as binary 'yes' or 'no' we implemented the likert scale. Creating a continuum better captures the perceived nuance of coder judgements.

To address the issues that coders have with the user rights variable, in an earlier version of the coding manual we made the decision to allow coders to select all that apply, and to specify that we were interested only in those involved in the collaboration. While this may not capture all users of the resource-(s) in all cases, it helps us to better describe the main phenomenon of interest – the collaboration.

We may not be able to remove the complexity of these difficult-to-code and important variables, but we can attempt to create the most user-friendly tool possible to assist research and theory building, and the support of collaborators who wish to use the tool to reflect upon and improve their efforts and learn from others.

4.5. What are the implications of our findings for collaborations?

Both collaboration specialists and general conservation practitioners acknowledge the complexity, difficulty, and necessity of collaborative efforts due to the rapidity and scale of environmental degradation. Due to this, methods for assessing and adjusting collaborative efforts are both desirable and needed, and sticky variables can assist in identifying particular elements of a collaborative that need special attention and long-term monitoring.

For many of the non-sticky variables, it is apparent to practitioners what ideal conditions are for success, and experience can be supplemented by both peer-reviewed and gray literature knowledge bases. In many cases, however, sticky variables are more difficult to measure, influence, and control in attempting to carry out collaborative conservation on-the-ground. In directly acknowledging this complexity and exploring the potential reasons for stickiness, our work can assist practitioners in flagging elements of their collaborative work that may be subject to sudden change, or which need to be reassessed over time. Sticky variables may also indicate to practitioners where they could use increased support via knowledge-sharing (e.g. social capital and trust), and tools (e.g. measuring temporally sensitive variables over time).

5. Conclusion and recommendations

In this article, we have introduced a set of variables selected to code and assess a wide range of cases of collaborative governance of SES, including a critical approach aiming to troubleshoot and provide feedback and recommendations for improving the coding manual used to enter cases into the database. Having a large number of cases coded will allow us to learn more about which variables are the most important for effective governance of SES and which variables are most likely to affect outcomes.

The variables that were identified as difficult to code in at least 3 of the cases were: trust and social capital; user rights; user boundaries; shared vision & long-term commitment; variety and flexibility of institutions; collaboration objective, environmental outcomes; and social, political or economic outcomes. Reasons found for their stickiness range from patchiness of the process, fluidity over time, complex human aspects related to the variable, and methodological challenges. In highlighting the inherent complexity of these variables and potential underlying reasons for their stickiness, special attention can be paid to these elements while studying and implementing collaborative efforts.

These findings also point at the need to further integrate interdisciplinary approaches to better understand complexities of SES, especially regarding the integration of theoretical and methodological insights to study human behavior and interactions. As a result of this identification, changes were made to the coding manual (version 11, in preparation) that aim to improve their codability and usefulness.

Finally, with regard to the practice of collaboration, this identification and analysis of sticky variables provides insight into elements of a collaboration which may be difficult to design and monitor. Sticky variables represent variables that should be regularly revisited among the collaboration partners, and the strategies related to them should be adaptable with processes in place for collective assessment and adjustment. This analysis also flags some variables that a collaborative may choose to monitor and measure using methodologies that account for their variability both spatially and temporally, and which acknowledge the human and social complexities underlying some of the sticky variables.

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ORCID

Aireona Bonnie Raschke http://orcid.org/0000-0001-5883-2713
Jessica Cockburn http://orcid.org/0000-0002-3954-7340
Paúl Cisneros http://orcid.org/0000-0003-0562-283X
Anahí Ocampo-Melgar http://orcid.org/0000-0003-3135-6037
Candice Carr Kelman http://orcid.org/0000-0002-0202-4722

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