From nouns to verbs: How process ontologies enhance our understanding of social-ecological systems understood as complex adaptive systems

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Abstract
1. Research on social-ecological systems (SES) has highlighted their complex and adaptive character and pointed to the importance of recognizing their intertwined nature.
2. Yet, we often base our analysis and governance of SES on static and independent objects, such as actors and resources which are not well suited to address complexity and intertwinedness. This bias, which is largely implicit, has its roots in substance ontologies that have influenced most of contemporary science.
3. This paper argues that it is useful to critically reflect on this ontological grounding and develop SES research from a process ontological perspective.
4. Key insights are that process ontological concepts such as process, event and possibility space are able to overcome the dichotomy between the social and the ecological and allow for a conceptualization of continuous change (dynamism) that enhances our understanding of SES as truly intertwined and complex systems.
5. This will enable SES researchers to conceptualize problems as well as corresponding solutions in novel ways which will ultimately support the development of novel governance approaches, from rethinking the aims of policies from managing people towards managing relations between and among people and the natural system.
6. To fully tap the potential which comes with a change in worldview towards a process ontology, changing research approaches and ways of abstracting are required.

KEYWORDS
complexity, dichotomies (or dichotomy nature/society), events, relational ontologies, social-ecological systems, substance ontologies, the practice of abstraction

1 | INTRODUCTION

Social-ecological systems (SES) are commonly conceptualized as complex adaptive systems in which humans and nature are deeply intertwined (Folke, Biggs, Norström, Reyers, & Rockström, 2016; Levin et al., 2013; Preiser, Biggs, Vos, & Folke, 2018). They consist of a complex web of social-ecological relations in constant evolution and need to be conceived of as one integrated system instead of two systems that exist independently prior to their interaction (Rademacher, Cadenasso, & Pickett, 2018; Schoon & van der Leeuw, 2015). Change is inherent and endogenous in SES and emerges from actions and interactions between diverse human and nonhuman...
actors that continuously adapt to the outcomes they jointly create (Levin et al., 2013). While endogenous change and intertwinedness are by now widely acknowledged characteristics of SES, doing justice to them in how we study and govern SES still remains a critical challenge (Cooke, West, & Boonstra, 2016; Fischer et al., 2015). In particular, there is a tension between our empirical understanding that acknowledges the complexity of SES, and the frameworks, concepts and methods we use to study and govern them. We hypothesize that the origin of the tension lies in an often unconscious, or rather habitual and implicit grounding of much of SES research in substance-biased ontologies (May, 2005). This grounding is implicit and habitual because an ontology is rarely consciously chosen. Substance-biased ontologies manifest themselves in the concepts, methods and frameworks SES researchers are trained to use, and use on an everyday basis—indeed of any explicit connection with the ontological realm. However, the effects of this connection may have far-reaching consequences for our ability to conceptualize SES as well as for the kind of questions we can ask about SES.

An ontology defines what a SES is, what it is composed of or what its main characteristics are. Substance ontologies cover a broad set of perspectives—from arguing that the world is composed of ideal forms, to only particles. Additionally, they might formulate hypotheses on specific entities that populate the world, such as the idea that subjects are rational, or boundedly rational. What permits the grouping of such diverse positions under the term ‘substance ontologies’ is that they all see the world as composed of entities that are independent of each other. In other words, entities are primary elements; they exist prior to any interaction or relation with another entity. We argue that basing SES research on a substance-biased ontology may impose certain categorizations to the study of SES that are not well suited to explore their constantly changing and intertwined nature.

In recent years, process ontologies have been proposed in several fields as an alternative ontological grounding that may be better suited for complex and changing systems, such as those found in biology (e.g. Nicholson & Dupré, 2018), anthropology (De la Cadena, 2015), human geography (e.g. Stark, 2017), sustainability research (Cooke et al., 2016; Kaaronen, 2018) and the study of complex systems in general (Weinbaum, 2015). These ontologies see the world as composed of interdependent processes, constituted by their relations with many other processes. Relations and processes are thus the primary elements; they exist prior to the entities that they may give rise to. We argue that a process ontology aligns better with an understanding of SES as intertwined, complex adaptive systems, since the concepts it offers take as a starting point that change is the constitutive characteristic of reality.

The aim of this paper is to (a) critically reflect upon the fundamental assumptions, that is, the ontological grounding, that underlie the concepts, frameworks and methods commonly used to study SES in view of (b) discussing the potential of process ontologies as an alternative ontological grounding that may help overcome the challenges outlined above and enhance our understanding and governance of SES.

In recent years, there has been a rise in approaches that incorporate elements of process thinking into SES research (see, e.g. Alonso Roldán, Villasante, & Outeiro, 2015; Cooke et al., 2016; Giusti, 2018; West, 2016). This indicates the need for reflection and more explicit consideration of the ontological commitments our research is based on. We base our analysis on an enquiry as to whether the concepts, frameworks and methods we use—and that are based on these commitments—satisfactorily convey endogenous change and intertwinedness as SES main characteristics. While all conceptualizations are abstractions, and therefore simplifications of reality, the point that we are trying to make is that the way such abstractions are done matters. The underlying belief over what exists (i.e. ontology) matters in guiding which abstractions are possible and which are not. Yet, even though all abstractions are simplifications of reality, our point, on the basis of the works of Whitehead (1925, 1978, 2006), is that process ontologies allow for abstractions that do not simplify in a way that limits our ability to conceptualize SES as intertwined complex adaptive systems.

We begin with a short introduction to substance ontologies, the basis of much of modern science. We continue by demonstrating how substance ontologies manifest in SES research to different degrees and sketch out their implications. We then present how process ontologies differ from a substance view and introduce several key concepts (process, relations, events, possibility spaces and dynamism). Once the core elements of this approach are laid out, we apply process thinking to SES. We discuss the implications of such a shift in paradigm for addressing the intertwined nature of SES, for understanding change, and for developing concepts. We conclude by elaborating on the potential of such a paradigm shift: Next to resolving the above-mentioned tensions between our understanding of the key properties of SES on the one hand, and the methods and frameworks that we use to study them on the other hand, this paradigm shift will contribute to reshaping and redesigning policies from managing people and ecosystem units towards managing relations between and among people and the natural system.

2 | SUBSTANCE ONTOLOGIES: A WORLD OF OBJECTS DESCRIBED WITH NOUNS

Before we start introducing process ontologies, it is important to get a clear—although synthetic—understanding of substance ontologies and why they are problematic for SES research. Substance ontologies have their origin in the Western philosophy of, among others, Plato and Descartes. They implicitly underlie much of today’s Western science and have shaped the frameworks, theories and methods we use (May, 2005). The dominance of this worldview in the study of SES is not surprising precisely because substance ontologies are the most common ontologies found in science today and other options are rarely considered (Kaaronen, 2018; Nicholson & Dupré, 2018).
2.1  |  Priority of being over becoming: An entity exists prior to its interaction with other entities

According to substance ontologies, reality consists of beings that are considered the fundamental components of what exists (Robinson, 2018). These beings (or entities) have essences which refer to a set of qualitatively immutable properties (Santos, 2015). They exist independent to any particular instance. For example, particles are said to exist, independent of any particular particle. This means that changes occur only to particular instances and therefore do not change their essence, which is immune to change. From a substance perspective entities or objects have priority over the processes that create them. Becoming is not a process of formation but a secondary phenomenon. Such a view assumes that entities exist before they interact. This makes it very difficult to conceive of anything as being social-ecological, that is, constituted by social and ecological processes. This view conceptualizes a social-ecological system as a set of social and ecological entities (constituting subsystems) that exist independently before they interact to produce social and ecological outcomes. These outcomes, consequently, need to be explained in terms of and reduced to what existed beforehand. Such reasoning risks missing aspects of intertwinedness that are only revealed during the process of interaction. These aspects may, however, be critical for understanding social-ecological phenomena. For instance, conceiving of a landscape consisting of forests and communities as an intertwined social-ecological phenomena, Comberti, Thornton, de Echeverria, and Patterson (2015) argue that there is mutual reciprocity between the services societies withdraw from ecosystems and the dependence of societies on ecosystems, in such a way that both are better conceived as co-constituted. This means that the state of the ecosystem at any given moment cannot be understood in purely ecological terms. This begs the question: Can we really understand and explain what a social-ecological landscape is without taking into account constantly changing past and present processes of interaction, that at any moment influence, support, enable and condition—and ultimately define what the communities and the forest are?

2.2  |  The dichotomies of reality

The difficulty arises not only from processual aspects being neglected, but from the fact that the social and the ecological are considered to be fundamentally different realms. Process philosophers have highlighted that substance ontologies typically introduce a distinction between the real, that is, the objective, and the perception of instances of it in time and space, that is, the subjective. This separation is to be understood as a fundamental ontological distinction, that is, as referring to two qualitatively different realms. Process philosophers have called this separation between two realms a ‘bifurcation’ (Whitehead, 2006). Substance ontologies operate with a set of interrelated bifurcations: the subjective is distinct from the objective, the natural is separate from the social, including subjective interpretations of the natural. Indeed, for whatever is considered ‘objective’ substance perspectives reserve the so-called ‘primary qualities’, that is, attributes such as motion, numbers, state of matter, etc. These are inappropriate to study most social interactions, which severely limits what can be studied from this perspective. Consequently, these realms are analysed separately and only integrated in the framework of inter- or transdisciplinary practice which often encounters several difficulties (Lélé & Norgaard, 2005). The dichotomies inherent in substance ontologies thus prevent conceiving the intertwinedness of the social and the ecological, or the social and the natural, as being co-constituted.

2.3  |  The practice of developing concepts from a substance perspective

Concepts are the tools we use to make sense of reality in general and of the problems we face in particular. Concepts constrain and orient our thinking in that they determine the kinds of problems we can perceive as well as the space of possible solutions. For instance, if a certain abstraction (e.g. an entity) has a defined set of properties, solutions to problems involving those entities will need to be formulated by reference to those properties. In this sense, our available concepts already embody the space of possible solutions, and different concepts allow for novel perspectives and solutions. The substance-biased view understands the development of concepts as the discovery of substances and rules that exist out there, immutable. Concepts are thus fully meaningful independent of the context in which an entity develops, including the relations it enters with other entities. When substance-based concepts are used as basis for the design of solutions to problems, they risk leading to unintended outcomes because an entities’ history or relations to its environment have not been taken into account. Lansing et al. (2017) have demonstrated how standardized and decontextualized blue-print solutions such as the introduction of green revolution practices in Bali in the 1970s led to increased pest outbreaks because of a disregard of strongly contextual practices, such as collective and synchronized irrigation schedules and pest management practices which are the result of co-evolutionary social and ecological processes. Substance-based concepts correspond to, or ‘mirror’ immutable substances. Therefore, they may be limited in how well they can account for change inherent in co-evolutionary processes and the contextual practices these lead to. This approach is typical of a focus on immutable substances and substance-based concepts and points towards the need for a different ontological grounding for SES alongside a different way of making abstractions.

2.4  |  Implications of substance-biased perspectives for SES research

Above, we have identified the priority of being over becoming, the dichotomies of reality and a particular way of abstracting concepts,
as key characteristics of a substance ontology. This section elaborates in more detail how ontology ‘does’ the work (Table 1), that is, how a certain way of viewing the world influences the frameworks and theories we develop, methods we use and ultimately the research and policy insights we obtain. We illustrate the influence of substance-biased ontologies on SES research through the example of two ‘research tendencies’: equilibrium thinking (building on the works of Cote & Nightingale, 2011; Preiser et al., 2018) and the tendency to separate the social and the ecological into distinct subsystems. We show how research tendencies influence the choice of frameworks, approaches and methods. Note that these are illustrative examples intended to help clarify how ontologies affect the way we research SES. We are aware of the many nuances in these tendencies that reflect different degrees of substance bias and the recognition of the need to acknowledge continuous change or overcome the dichotomy, however, doing justice to this diversity is beyond the scope of this paper.

The tendency to think in terms of equilibria can be illustrated by the study of ecological or social-ecological regime shifts (e.g. Hughes et al., 2017; Lade, Tavoni, Levin, & Schlüter, 2013; Scheffer, Carpenter, Foley, Folke, & Walker, 2001). In this research, ecosystems or SES are understood as systems that may exhibit multiple stable states (Holling, 1973; Lade et al., 2013). The focus of research and governance lies on maintaining the system in a desirable state by preventing a shift towards a different (undesirable) equilibrium (Crépin, Biggs, Polasky, Troell, & de Zeeuw, 2012). Such a shift towards an alternative state is understood as the result of one or several external variables that may operate at different timescales (fast and slow variables, see e.g. Crépin, 2007). An iconic example is the shift of a clear water to a turbid lake driven by nutrient inflows from agriculture (Carpenter, 2005). The focus on stable equilibria and the drivers that shift systems from one equilibrium to another has its roots in giving priority to stability over change, which is one of the characteristics of substance-biased ontologies. This perspective has influenced frameworks commonly used in SES research such as the cup and ball landscape where the system is represented by a ball that stabilizes in different valleys representing different basins of attraction. External drivers can push the system across a threshold from one valley to another. Changes within the landscape caused by forces external to the system may make existing equilibria easier to reach or create new ones. Dynamical systems theory and mathematical analysis have been an important theory and method to identify stable states, assess their stability and identify transitions between states (Hughes et al., 2017; Lade et al., 2013). The limitations of such a view for our understanding of regime shifts in the Anthropocene have recently been recognized and researchers have called for a conceptual shift away from an emphasis on the maintenance of ecosystems at equilibrium towards a reality where ecosystems are much more dynamic and increasingly different from what they have been before (Hughes et al., 2017). As Arthur (2014) summarizes when discussing equilibrium thinking in economics, ‘there is no scope for improvement or further adjustment, no scope for exploration, no scope for creation, no scope for transitory phenomena, so anything in the economy that takes adjustment—adaptation, innovation, structural change, history itself—must be bypassed or dropped from theory. The result may be a beautiful structure, but it is one that lacks authenticity, aliveness, and creation’.

The tendency to think in terms of equilibria

| Tendencies in SES research | Roots of the tendency in substance-biased ontologies | Consequences for SES research and practice | Examples from SES research |
|----------------------------|---------------------------------------------------|------------------------------------------|---------------------------|
| Equilibrium thinking       | The focus of substance-biased ontologies on stable and well-defined entities that are characterized by fixed properties may support a type of thinking that focuses on the stability of entities and systems. Loss of stability or change in equilibria is caused by shocks that are external to the entity or system | Analyses focus on stable states of a system and how the system shifts between them, often as the result of an external disturbance such as climatic or anthropogenic drivers. Common frameworks are the cup and ball diagram or hysteresis curves. Use of mathematical tools such as stability analysis or causal loop diagrams to identify equilibria and assess their stability | Social-ecological regime shifts (e.g. Hughes et al., 2017; Lade et al., 2013) |
| Separation of the social and the ecological | Substance-biased ontologies introduce a distinction between subject and object or social and natural. This distinction resulted in a fragmentation into social and natural sciences with approaches and methods that are often incompatible. As a consequence, it may become difficult to go beyond a view that treats the social and ecological as separate subsystems that influence each other towards a view of a single, co-constituted entity | Conceptualizations of SES include the social and the ecological as two separate domains that are connected through links. It is assumed that both systems can be studied separately and then linked through a few interactions. Data are often collected separately for one or both domains | Frameworks that depict a social system and an ecological system that are linked through two arrows representing feedbacks between them (Berkes & Folke, 1998). The SES framework (Ostrom, 2007) that separates a SES into four first-level tiers, two ecological (resource unit and resource system) and two social (resource user and governance system) |
draws our attention away from the continuity of change—and away from methods and approaches that can address this continuity.

Examples of the tendency to separate the social from the ecological are particular understandings of the notion of 'ecosystem services', notably those that reduce the concept of ecosystem services to their instrumental value for humans (Raymond et al., 2013 refer to the 'economic production' metaphor for understanding ecosystem services). This is because, as Preiser et al. (2018) note, 'economics and other social sciences generally viewed natural systems as non-dynamic resources for extracting capital gains or providing the basis for livelihoods'. An economic production understanding focuses on the production capacity of ecosystems for humans, at the expense of possible feedbacks between human and natural systems. This encourages an understanding of the social and the ecological as being distinct and unconnected realms. This tendency also manifests itself in many human–environment frameworks, such as the SES Framework (Ostrom, 2009). The framework requires researchers to use variables from different tiers, such as ‘resource system’, ‘resource unit’, ‘users’ and ‘governance system’ which separates the social and the ecological before the analysis even begins. Concepts are arrived at by a process of abstraction that mirrors the ontological reality a researcher consciously or unconsciously subscribes to. As large parts of Western science see reality as composed of fixed substances (May, 2005), it is not surprising that the clear boundaries between stable objects and the distinction between the cultural or social and natural or ecological manifest themselves in the frameworks we use. The process of abstraction on the basis of substances thus naturally leads to such variables, or concepts, and arranging them via tiers in ways where the social and ecological belong to different realms.

There may be two possible consequences for SES research that researchers should be aware of: First, this tendency may prevent the researcher from seeing and understanding the social and the ecological as co-constituted by processes from both realms and intertwined, thus potentially missing important elements necessary to understand a particular SES (Comberti et al., 2015). Second, researchers might be leaning towards conceptualizing and formulating SES problems in specific terms (e.g. in terms of the SES framework variables), thereby excluding other, different conceptualizations which are potentially enriching and which would allow for different processes of interaction in view of developing very different solutions. The aforementioned difference is not a difference in the degree of abstraction (e.g. what to focus on and what not, and to what extent) but rather in how we abstract and conceptualize reality itself. Indeed, while the need for a plurality of perspectives has been highlighted (Bousquet, Robbins, Peloquin, & Bonato, 2015; Peterson et al., 2018), substance ontologies only allow for certain conceptualizations (i.e. those that mirror substances) and not others. Different substance-biased abstractions (such as different human–environment frameworks) provide different perspectives, but they still remain within a conceptualization that is limited in its ability to address continuous change and becoming.

3 | PROCESS ONTOLOGIES FOR SES RESEARCH: A WORLD DEFINED BY PROCESSES AND DESCRIBED WITH VERBS

Process ontologies have been discussed in the realm of philosophy since the pre-Socratics, by Heraclitus in particular, to whom the expression ‘everything flows’ is attributed. Process thinkers put forward a worldview where constant flux and dynamism dominate. For the purposes of this paper, we focus on the work of Alfred North Whitehead (1925, 1978, 2006), which we take as the founding father of the contemporary approach to process ontologies, and we also present some works by James (1904), Deleuze (1990, 1991, 2004) and Deleuze and Guattari (2002, 2014) together with some of their readers such as Stengers (2015) and Weinbaum (2015). Of course, there are many more and we invite the reader to consult Rescher’s (1996, 2000) or DeLanda’s (2006, 2016) work for an overview of contemporary process thought. It is noteworthy that while process ontologies are often contrasted to substance ontologies, they are also different to other popular perspectives such as social constructivism and critical realism (see Srnicek, 2007).

3.1 | Becoming precedes being: Everything exists through processes and relations

In process ontology, reality consists of ‘processes’. Processes interact with many other processes which jointly give rise to ‘events’. Processes and events are fundamentally the same thing: the only difference is that events are sets of processes that are experienced by a being, which delineates them from the overall flow of processes. For example, each breath of a human being is an event, that is, a set of processes experienced by the human being. In this event, many other processes come together—the production of oxygen by surrounding trees, the extraction of such oxygen by our lungs, etc. Conceiving of breathing as an event is thus fundamentally different to conceiving of it as a property derived from the essence of a human being, that is, as a property of the lungs of human beings. Conceiving of breathing from a substance-biased perspective tends to limit breathing to the activity of the lungs, whereas a process-based view highlights processes and relations such as the production of oxygen, that go far beyond those we normally consider when we talk about the essence of a human being.

What then, according to a process ontology, ‘is’ being? Being can be understood as a sequence of events. In other words, a human organism, for instance, is a state of becoming upheld by many repetitive events (each realized by many processes) over a certain period of time, one of which is breathing (Nicholson & Dupré, 2018). Put differently, entities exist over a sequence of events that are brought about by recurrent processes. They do not exist prior to any process, as they do from a substance perspective, but rather, are created by a combination of processes that interact and are maintained. This is thus different to our familiar
understanding of the term ‘process’ understood as a change in the state of an entity or a relation between entities. Such an understanding assumes that these entities already existed before anything happened to them. Conceptualizations of ecosystem services that view ecosystem services as produced by nature for the benefit of humans (nature’s free gift to humankind; Potschin & Haines-Young, 2011) are an example of such an understanding. Here, processes refer to the relation and material or immaterial flows between an ecosystem and the humans that benefit from it, where the ecosystem and humans exist independently and prior to their interaction. From a process ontological perspective entities, understood as events, unfold within ‘possibility spaces’. Possibility spaces are the sets of possible processes at any given moment in time and space that can enter an event. As such, they shape the possibility of the future unfolding of the event. An event exists within a constantly changing world of processes and as such has many antecedent events. Strictly speaking, an event ‘is’ its antecedent events. The history of an event thus matters for understanding the possibility space for its current unfolding. At the same time, there are processes that remain possible but are not actualized throughout the unfolding of an event. For instance, a community may learn from other communities about how to manage a certain resource. This knowledge can be applied for managing their own resources and thus actualizes the process of learning—but this need not be so, in which case it remains only a possibility. Furthermore, the possibility space is constantly modified by the ongoing interaction and evolution of actualized events. Staying with the community example, if cross-community learning is ongoing and part of this learning indicates that certain forms of managing the resource have proved ineffective in one place in the past, it is unlikely that those relations will actualize in another place, thus modifying the possibility space of available relations to realize at a given moment. It is this continuous interplay between what is realized and what is possible that will determine events—and not accounting for this interplay will mean that we are likely to miss important aspects of the phenomena to be understood and explained (e.g. whenever we try to account for intertwinedness from a substance-biased perspective, see discussion above). Figure 1 summarizes the key aspects of an understanding of being as a sequence of events.

Understanding being as events that unfold according to continuously changing possibility spaces highlights a core characteristic of process ontology: that change is more fundamental than stability. Process thinkers Dupré and Nicholson argue that the term change is inadequate because it presupposes entities, or substances (Nicholson & Dupré, 2018) that exist before they can change. Indeed, SES researchers rather refer to ‘continuous change’ (Schlüter, Hinkel, Bots, & Arlinghaus, 2014) where Dupré and Nicholson argue for the use of the term dynamism as a substitute for ‘change’.

The tension between a complexity perspective and the frameworks and methods used to study SES that are inherited from substance thinking is the most apparent when focusing on continuous change. While not all SES research takes a complexity perspective, complexity research has had a strong influence on how researchers conceptualize SES. However, substance thinking commits to an understanding of reality in terms of stable entities with sharp boundaries, which is incompatible with complexity thinking as Rogers et al. (2013) point out since it limits our possibilities to

**FIGURE 1** Being is understood as a sequence of events. Every event can be realized by many different ‘processes’ coming from a variety of different realms, such as the biological, ecological, social, cultural, aesthetic, etc. But not all processes that could enter an event are realized because the event is always abstracted from a particular point of view specific to a particular instance of being, such as its position in space and time and its history of interactions. The ‘possibility space’ defines the set of processes and their interactions that are possible at any given moment. The distance of points on the possibility space from the event symbolizes the likelihood of them entering the event (i.e. the distance symbolizes attractors). As an example, we can think of the learning processes between communities managing a natural resource discussed above where it may be unlikely that ineffective practices will actualize in another place. Those points at the back of the possibility space (and in the valley) cannot enter the event at that given moment. Here, we can think of practices realized by earth-beings (see below). Someone not knowing nor being familiar with them will not realize them—at least not at that particular moment. But this might change if new processes enter the sequence of events (e.g. travelling to the Andes, reading books by De la Cadena, etc.). The possibility space records interactions and reconfigures continuously as processes actualize in events. Being is nothing over and above this continuous unfolding of ever evolving events. Furthermore, the possibility space depends on the ‘conditions of experience’ (symbolized by the thick black lines) of beings which refers to what allows experiences to realize. These are—in the widest sense—defined by epistemological capacities and practices of beings, such as having (or not) a language at one’s disposal, or devices that allow novel experiences (e.g. technical devices such as microscopes). But also whether or not a being has a consciousness, or a central nervous system. Beings can be very different, given that experience is not limited to a human faculty. Human, conscious experience is just one way of experiencing, next to other, unconscious ones.
conceptualize change. The concepts of process, event, possibility spaces and dynamism are useful for studying and governing SES because they provide alternatives that allow us to conceptualize and study continuous change as it shapes the entities and phenomena we see and create novel ones. They facilitate moving beyond equilibrium thinking, where change is seen as an exception, and analysis focuses on investigating the stability of this equilibrium to perturbation. As Brian Arthur notes (pers. comm.), systems in equilibrium are dead. What this means is that there is no change in such systems.

For example, when conceptualizing processes of emergence, SES researchers repeatedly highlight the importance of change in the form of co-adaptive (Lansing & Kremer, 1993) mechanisms. Lansing and Kremer (1993) describe the emergence of a highly complex crop management system on Bali as a process of co-adaptation which should be understood as continuously evolving in time and space, involving farmers, ecological systems, cultural practices and the physical geography of Bali. What these individual components are (and why they do what they do) cannot be understood without reference to this very process of co-adaptation. The emergent property is therefore not something that can be understood and explained without making reference to this very process, or put differently, that could be viewed as a simple combination, aggregation or particular organization of the individual components. Rather, the emergent phenomena might well be accounted for by a process perspective which understands the process of co-adaptation in terms of evolving possibility spaces of events, where novel processes enter and connect events and shape the possibilities for future unfolding (Protevi, 2006). In a similar vein, resilience thinking (Folke et al., 2010) and transformation research (Moore et al., 2014) have already gone to great lengths to give change a more dominant position. The process ontological perspective described here complements this endeavour by providing an ontological foundation that allows to conceive of a transformation as a dynamic process, not a bridge between two endpoints, or two equilibria.

3.2 | Beyond dichotomies: Processes can be social, ecological, subjective, objective—Together they constitute events

According to our understanding of being as events, and change as dynamism, it not only follows that entities do not pre-exist their interaction but also that events as flexible units do not have sharp boundaries. This means that the processes that realize and, in the end, define events, continuously change, in line with a changing possibility space. At the same time, events do not ontologically and epistemologically belong to any category such as the social, the ecological, the cultural, the aesthetic, and neither do they distribute subject and object roles. Events are constituted by many processes, some of which are ecological, some social. Processes in an event bring together all different realms, subjective experiences, social phenomena and ecological dynamics. We should not a priori exclude any realm as a result of a theoretical commitment or in principle.

Many SES studies still fall short when it comes to capturing the intertwined nature of SES (Fischer et al., 2015; Guerrero et al., 2018; Kramer et al., 2017; Turner et al., 2016). Some current approaches in SES research aim at crossing different realms. An example is the Multiple-Evidence Base approach (Tengö, Brondizio, Elmqvist, Malmer, & Spierenburg, 2014), in which different types of knowledge are brought together in the process of knowledge co-production highlighting what can be integrated and what cannot. Another approach can be found in Cooke et al.’s (2016) work on ‘dwelling’ as an embodied connection between the human and the biosphere. Bringing together different realms does not mean that we need to account for every aspect of the event. Processes in an event will be inextricably social as well as ecological up to a point where this distinction does not apply in a meaningful way.

We can illustrate how process thinking can help overcome this dichotomy through the example of a fishing community and its organizing events, which are intrinsically social-ecological. Talking about the fishing community as a series of events means understanding it in terms of the processes that realize it in space and time, that is, events from a variety of different domains, social as well as ecological, such as fishing, which, in turn, are constituted by fish reproduction, fishers’ relations to particular fishing gear and target species, fish species and their relations with each other, and processes such as the specific weather on a fishing day, or recurrent festivities such as religious or spiritual celebrations and so on and so forth. Hence, adopting a process perspective allows one to think of the SES as one system of processes, not as a system with different subsystems, the social and the ecological. Said otherwise, there is no such thing as the objective and real ecological world versus the constructed and subjective social world, but a system in which relations can only be defined relative to one another across traditional dichotomies.

3.3 | The practice of developing concepts from a process perspective

Where the substance-biased view conceives of the development of concepts as the discovery of substances and rules that exist out there immutable, process philosophers instead encourage us to critically question whether our concepts correspond to the ever-evolving reality. Put differently, what matters in a world where dynamism is more fundamental than stability, is whether we are conceptually equipped to address the challenges of a world in constant change, and this should be the guiding principle in creating and revising the concepts that we use. It is the event which provides the basis for this creative, conceptual activity, precisely because events do not have sharp boundaries that would ‘limit’ the form/scope of concepts.

Every event in a SES depends on many interacting processes in a particular place and point in time. SES outcomes are thus highly
context-dependent. What does this entail for abstracting and generalizing? As pinpointed above, we need concepts to generalize, reduce complexity and build theoretical insights comparable across cases. Although a process perspective emphasizes the role of context in analysis, this does not make it incompatible with the theorizing endeavour. On the contrary, we argue that it is by engaging in process-based conceptual developments that we can achieve theoretical insights that do not force us to sacrifice the richness of the context. The first question to be asked is ‘what relations take place?’ and what these relations mean for sustainability, that is, what realizes them, what are the threats to those relations taking place or the obstacles to desired performed relations. Second, do our concepts capture these relations in a meaningful way, are they adequate to do so? Theoretical insights can thus be gained by comparing sustainability outcomes with respect to processes and relations and the conceptual descriptions rendering them intelligible and meaningful. To realize this potential, we need a mode of making concepts that gives room to all dimensions of experience (e.g. mental, sensory, etc.), given that relations are revealed in experience.

A good example of how novel concepts that do justice to context could look like is given by anthropologist Marisol de la Cadena redefinition of the concept of ayllu (De la Cadena, 2015; De la Cadena, Risør, & Feldman, 2018). In Andean anthropology, the concept of ayllu is typically understood as a form of property right, referring to collective ownership by Andean communities of the land they inhabit. De la Cadena points out that such a definition distinguishes between a subject (the people) and an object (the land) and establishes a relation of property and of habitation. She, by contrast, argues that the ayllu is something that ‘takes place’. It takes place in time and space and by taking place people and the land exist together as earth-beings. This has great consequences for understanding the lives of these communities, as De la Cadena points out: ‘if people and land are not separate, there cannot be worship relationships. There aren’t separate people who venerate the mountains, they are [together]’ (De la Cadena et al., 2018, p. 164 our translation). In other words, ayllu ‘taking place’ as an event means that the behaviour of communities cannot be analysed through theories that make a distinction between the subject and the object. In this case, the community and the land cannot be decomposed into something more fundamental, contrary to what a substance ontological perspective would require, that is, separating human beings from mountains. Trying to understand this system from a substance perspective is unlikely to lead to knowledge that would allow, for example, successful management interventions into this system. Rather, understanding these as events allows to adapt the type of concepts that one reasons with beyond any bifurcations, in view of generating contextualized knowledge that would allow adapting management approaches, but that would also allow for a cross-case comparison with respect to sustainability outcomes.

From a process perspective, our concepts should thus never be treated as set and given but should always be open to empirical investigation. This is because what concepts were developed for is constantly changing too. A process perspective provides the much needed flexibility when creating/revising concepts to conceptualize sustainability problems in novel ways, as well as to develop novel solutions. As such, the task of the researcher is to ‘think with’ a changing world instead of trying to ‘represent it as it is’.

4 | CONCLUSIONS

4.1 | The need for a paradigm shift: Overcoming the tension between our understanding of SES and how we study/govern them

There is consensus that basing SES research on a separation of the social from the ecological is inadequate to explore the kind of wicked problems that characterize sustainability research (see e.g. Roux, Nel, Cundill, O’Farrell, & Fabricius, 2018). Substance-oriented methods and frameworks have difficulties accounting for the properties of complex adaptive systems because of their focus on stable objects and the separation between two independent classes of objects, social and ecological, whose relations are only secondary. Key insights from our discussion are that a process ontology has the ability to overcome the dichotomy between the social and the ecological that impedes understanding SES as truly intertwined and that it enables developing abstractions that are sensitive to contextual processes. Ultimately, this will also inform the frameworks and methods that we can apply for SES research and resolve the tension between our understanding of SES as complex and intertwined systems and how we study them.

A reflection on the implications of adopting a process perspective on research design can be found in Preiser et al.’s (2018) discussion of the features of complex adaptive systems. For Preiser et al. (2018), embracing complexity means adopting a stronger focus on relations and interactions, which are key elements of a process perspective. They emphasize the need to shift research attention from system elements to their interaction, the need to go beyond purely material causes to complex causality that operates beyond dichotomies, acknowledging that observers are always part of a system. This requires epistemological and methodological pluralism as well as a normative and ethical stance that asks from researchers to acknowledge that there is no objective viewpoint (in the classical philosophical sense) but that knowledge (or rather the point of view from which it is gathered) is always only partial and biased. These considerations point to the use of methods and approaches for SES research that are abductive instead of inductive or deductive (see Box 1).

4.2 | Looking forward: Novel perspectives for SES research and management

The potential of a process-oriented change in our fundamental conceptualization of SES, metaphorically described as a shift from nouns
to verbs, opens up opportunities for SES research and management. Indeed, we argue that conceptualizing SES from a process perspective may enable researchers to pose novel questions such as what constitutes social-ecological identity? Would fishers who select one particular fish species—despite markets signalling that other species might be more profitable—consider that a particular fish species is tied to their identity? What kind of relations are disclosed in such a relationship and how do they take place? Answering these questions will affect the approaches we use to study SES and affect the way we design corresponding policies and management interventions, from managing people towards managing context sensitive relations between and among people and the natural system.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

AUTHORS’ CONTRIBUTIONS
T.H., M.M.G. and M.S. developed the ideas and the conceptual approach leading to the manuscript; T.H. led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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