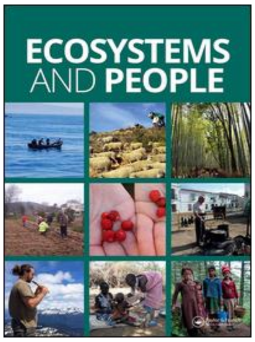

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PERSPECTIVE: THE SCIENCE-POLICY INTERFACE OF ECOSYSTEMS AND PEOPLE OPEN ACCESS Check for updates

Moving towards public policy-ready science: philosophical insights on the social-ecological systems perspective for conservation science

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ABSTRACT

The social-ecological systems (SES) perspective stems from the need to rethink the ways humans relate to the environment, given the evidence that conventional conservation and management approaches are often ineffective in dealing with complex socio-environmental problems. The SES approach conceives non-scientific and scientific knowledge as equally necessary in the process of management and public policy formation. Thus, the adoption of the SES approach must also serve to make better decisions about what kind of science and technology would be 'public policy-ready' (as well as also 'policy-relevant'); that is, a science oriented and conceived to provide concrete solutions to societal needs and demands. Here we review and reinterpret the SES perspective as a real paradigm change for conservation science. Under the lenses of philosophy, we try to untangle some weak points of the SES approach in order to advance to a conservation science closer to the process of science-based public policy creation and to enhance the intertwining with other types of knowledge. In this sense, we discuss how co-production of knowledge and decision-making process under the SES perspective are a huge step forward towards fulfilling the need to bring increasingly closer the spheres of science and policy, narrowing its interface.

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Introduction

The development and accumulation model followed by most countries in the world prioritizes maximization of economic benefits in the short-term in detriment of environmental quality, jeopardizing human welfare in the long-term and equitable distribution of wealth in the broad sense (see Dietz et al. 2003; Pouw and Gupta 2017; cf., Büscher et al. 2012).

Environmental conservation and management have traditionally been performed on a sectoral basis or focused on a single species (e.g., Simberloff 1998; Coppolillo et al. 2004; Smith and Sutton 2008). These approaches usually do not take into account interactions among different elements of the ecosystems and stakeholders (Simberloff 1998; Meffe 2002); neither do they incorporate pieces of knowledge other than scientific (Canagarajah 2002; Görg et al. 2014, 2016). Even more, academic knowledge generally comes in the form of external advice and not from a real joint work between science, community and management sectors (see Anderson and Valenzuela. 2014; Fernández 2016). This is actually a forced fragmentation of what should naturally be a cooperative interaction (or e.g., co-production of actionable knowledge; see Kirchhoff et al. 2013), and has led to multiple socio-environmental problems due, mainly, to conflicts of interests, communication issues and rejection from communities to support environmental policies (see Chapin 2004; Goldman et al. 2011; Dempsey and Robertson 2012; Fernández 2016). These conflicts have made evident the need for a more integrated approach for natural resources management (see Berkes et al. 2003; Folke et al. 2010, 2011; Manfredo et al. 2014; Bennett et al. 2015; Zafra-Calvo et al. 2017).

Ecosystem-based approaches (e.g., UNEP 2011) arose to partially address some of the problems derived from sectoral perspectives. They consist of a set of principles and steps focused on the interactions among subsystems to solve conflicts of interests, and introduce adaptive management as a novelty (Meffe 2002; Ojea 2015; Long et al. 2015). However, they lack of a sounder epistemological and pragmatic change related to the ways we conceive the social-ecological systems, co-production of knowledge and co-management (see below).

The social-ecological systems (SES) perspective (e.g., Martín-López et al. 2009; Ostrom 2009, 2010; McGinnis and Ostrom 2014) aims at understanding how elements and interactions that constitute an ecosystem, including humans and their activities, not only interact but interpenetrate with each other, and the results of these interactions-interpenetrations, including uncertainties, risks and reciprocal modifications (e.g., McGinnis and Ostrom 2014). The human element in the SES approach

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is referred as 'human societies *in* nature' as an nested system, instead of 'human societies *and* nature' (see Mace 2014; Martín-López and Montes 2015), and co-evolves with the ecosystems as a whole, as an integrated system, in an intimate and still indecipherable dialog (Berkes and Folke 1998; Berkes et al. 2003; Manfredo et al. 2014; Bennett et al. 2015, 2017). Although in the specialized literature there are recognized ten well-established frameworks for analysing social-ecological systems (see Binder et al. 2013), we will refer here to the most commonly used approach (see SESF in Binder et al. 2013), which was developed by prominent thinkers such as Carl Folke, Fikret Berkes, and Elinor Ostrom, among others (see e.g., Berkes and Folke 1998; Berkes et al. 2003; Ostrom 2009, 2010).

Broadly speaking, these authors understand the SES as complex adaptive systems, in which human societies are embedded in nature. The social component refers to all human activities that include economy, technology, politics and culture (e.g., McGinnis and Ostrom 2014). On the other hand, the ecological component of a SES refers to the biosphere; that is, to the part of the planet on which life develops (e.g., Folke et al. 2011). Both parts are interrelated, the limits of the system are arbitrary and depend on the questions, hypothesis or perspectives of analysis (Berkes and Folke 1998; Berkes et al. 2003). This new paradigm emphasizes that human societies, economies and cultures are constitutive parts of the biosphere which they transform, both locally and globally (Martín-López and Montes 2015; see below). At the same time, people, economies, societies and cultures depend on the biosphere, which shapes them, and therefore they co-evolve (Manfredo et al. 2014; Bennett et al. 2015, 2017).

Although in recent years the SES perspective has been gaining ground and momentum among some groups of conservation scientists (e.g., Balvanera et al. 2017 and references therein), its implementation is far from being hegemonic in the conservation arena (see Mehring et al. 2017). The most widespread conservation practices are still much closer to those defined and structured by their historical referents, such as e.g., Soulé (1985, 2013), but see the heated dispute called 'Anthropocene conservation debate' between this author and Michelle Marvier and Peter Kareiva, among others (e.g., Kareiva and Marvier 2012; but see Sandbrook et al. 2019).

The main objective of this perspective paper is to contribute to the environmental conservation community of scientists and practitioners by delivering with new and solid arguments, underpinned in a philosophical perspective, that highlight the potential of the SES approach. Hopefully, this in turn will contribute to a more direct and positive impact of conservation-related action-research (see Mehring et al. 2017). Through a critical re-interpretation, we seek to take out the current discussion on conservation science (its foundations, motivations, implications, approaches, etc.) from the swamp in which we believe it is (see Sandbrook et al. 2019); and help move it towards a more participatory, democratic, egalitarian, effective and transformative debate. Thus, as an objective derived from the first one above mentioned, we will try to show why we believe the SES perspective should be incorporated in the field of conservation science, provided that it paves the road among researchers, practitioners and actual stakeholders (see Mehring et al. 2017), and its effects reach all the way down to local implementation of science-influenced public policies.

Ecosystem services: between the innovative metaphor for social-ecological transformation and the key to the final commodification of nature

Although the SES approach was born independently of the concept of 'ecosystem services' (ES; see e.g., Walker et al. 2004), both approaches soon became associated, especially after the publications following from the Millennium Ecosystem Assessment (2005). Since then, the vast majority of researchers and institutions that work using the SES perspective rely (to a greater or lesser extent) upon the ES contested concept (see e.g., Dempsey and Robertson 2012; McAfee 2012; Büscher et al. 2012; Schröter et al. 2014). Ecosystem services are defined as the benefits that people obtain from ecosystems (Millennium Ecosystem Assessment 2005). This definition has recently been broadened to 'the contributions of ecosystems to human well-being' (see e.g., de Groot et al. 2010), to clarify that the interactions within ecosystems can be positive or negative.

The ES concept was first coined as a *metaphor* to highlight the social importance of natural systems, but it was soon, and not by chance, turned into an instrumental economic concept (see Gómez-Baggethun et al. 2010; Gómez-Baggethun and Ruiz-Perez 2011; Spangenberg 2011; Dempsey and Robertson 2012; McAfee 2012; Büscher et al. 2012; Schröter et al. 2014). In this sense, nature is considered a good or a commodity (see Gómez-Baggethun 2015), subjected to the human will of either use it sustainably, exploit it, alienate it or 'sell it out' (McCauley 2006 and references therein; cf.; McAfee 1999). The ES concept has triggered an intense and ongoing debate about whether it serves a conservationist cause or, on the contrary, it leads to nature commodification (e.g., McCauley 2006; Gómez-Baggethun and Ruiz-Perez 2011; Dempsey and Robertson 2012; Büscher et al. 2012; Brand and Vadrot 2013; Schröter et al. 2014; Gómez-Baggethun 2015; cf., Reid 2006; Costanza 2006; Marvier et al. 2006). Beyond this important debate, it is argued that an instrumental value of the ES concept itself could serve to provide social support to conservation strategies as protected areas (e.g., Martín-López et al. 2011; Palomo et al. 2014; Zafra-Calvo et al. 2017). This has to do with the strategy of developing a common language that helps to uncover the social benefits of conservation (see Moon and Blackman 2014; Bennett et al. 2015, 2017).

We should not ignore here the importance of another concept closely associated with ES, that is 'ecosystem integrity'; which can be understood as the faculty of an ecosystem to maintain its organisation in the face of changing environmental conditions (Kay 1991; Maass et al. 2016). The integrity of ecosystems is a multi-dimensional concept; that is, it involves and encompasses a wide set of criteria and variables of ecosystems in its analysis (e.g., energy capture, storage capacity, cycling, flow density, nutrient loss, respiration, transpiration, etc.; see Maass et al. 2016). It is important for us to highlight the link between both concepts, since changes in communities and ecosystem's degradation have systematically been affecting the ecosystem's integrity (e.g., Dornelas et al. 2014); what in turn has brought specific consequences for ES delivery, through changes in the dominant traits of the community and other key ecosystem's components affected (Maass et al. 2016).

The false dichotomy between instrumental and intrinsic values of nature

The controversy around the ES concept ignited the debate about whether nature should be protected because its 'intrinsic' or because of its 'instrumental' values. We believe that this dichotomy is obsolete for the conservationist cause (see Martín-López and Montes 2015). This thought is also reflected in the work of many people who are searching for other approaches to transcend this duality towards a better understanding of nature, for example, through relational values (Díaz et al. 2015a, 2015b; Chan et al. 2016; Pascual et al. 2017), ecocentrism or 'third position' (Moon and Blackman 2014; Gallardo 2015), or bio-cultural approaches (Rozzi 1997; Rozzi et al. 2015; Caillon et al. 2017). As stated by Martín-López et al. (2009), intrinsic and instrumental values are complementary provided the translation of the intrinsic values ideology into public policies may introduce a non-rational bias toward certain species (see Martín-López et al. 2011). We also believe that there is another possible cosmovision for ES: the *living* of nature, or the *living* of ES. We constitute nature and at the same time nature constitutes us. We live *with, from* and *in* the environment (see O'Neill et al. 2008). We humans grab and *appropriate* the nature to live it, where 'appropriation' means belonging and significance, and not at all privatization or commodification (see Escobar 2014).

A sense of respect and belonging for nature has somehow survived in Latin America over the centuries and over its colonization history (see López Ospina et al. 2000; Escobar 2014). This fact is evident, for example, in nations like Colombia, which has recently declared two of its rivers (i.e., Atrato and Cauca) as subject of law; or as in Bolivia and Ecuador, with an important percentage of indigenous population, which have incorporated the rights of the Mother Earth (Pachamama) or the Sumak Kawsay (the Good Living) in their Constitutions (see Zaffaroni 2012). While it is necessary to not sacralise or have a romantic vision of indigenous knowledge, the relationship that the pre-Hispanic societies of America maintained with their natural environment is worthy of being studied and resignified at present, taking care of not performing anachronistic and decontextualized interpretations (López Ospina et al. 2000). What we must rescue from all the heritage inherited from the indigenous communities are the contents of their deep philosophies, that supported production techniques, deeply rooted in their culture, in their conception of the world and of life, in the ways of relating to Mother Earth, to nature, in the way of relating to each other, and in maintaining a harmonious balance between ecosystems and people (see López Ospina et al. 2000; Rozzi et al. 2015).

Within their profound, plural and diverse value systems, the pre-Hispanic American cultures have, and care, very important common conceptions for the current conceptualization of the SES and their sustainability, and also for conservation science (see Rozzi et al. 2015). As a examples of this, we can mention the conceptualization of the human being considered as axis and fundamental subject of the development (i.e. in a broader sense than the one often used and assimilated to economic growth); the community as the generator of initiatives and dynamics for the solution of common problems; the pre-eminence of the interests of the community over the individuals; the harmonious coexistence between the human being and the nature to which it belongs; and ethics as a fundamental rule for the relationship among people and among communities (López Ospina et al. 2000; Rozzi et al. 2015). Not by chance today we see how a pre-Inca hydraulic system, known in Quechua language as '*Amunas*', could save the city of Lima (Peru) from a deep water crisis; since boosting this system could mean 35% more water availability during the dry season (see Ochoa-Tocachi et al. 2019).

Conspicuously, the Governments of Bolivia, Ecuador and Cuba have refused to join coalitions as the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) in a first instance, as they perceive these mainstream strategies of economic evaluation of ES as threatening mechanisms for indirect privatization of nature (Balvanera et al. 2012 and references therein; cf.; Brand and Vadrot 2013). In spite of this, it must be said that the IPBES is nowadays searching for a real reconciliation among the different ways of perceiving and valuing nature (Pascual et al. 2017; Díaz et al. 2018). Tightly related to this is the recognition of the inequitable power relationships across different stakeholder groups (see Berbés-Blázquez et al. 2016; Boonstra 2016; Pascual et al. 2017; Zafra-Calvo et al. 2017; cf., Brand and Vadrot 2013). In this sense, the new conceptualization of *nature's contributions to people* (NCP; i.e., these are all the contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life; see Díaz et al. 2018), emanating from IPBES, stands as a great promise to solve many of the problems that the ES concept brought with itself (see Díaz et al. 2018 and references therein). Beyond the current controversy about this new category of NCP (see e.g., Braat 2018), we understand that this much more plural, diverse, dialectical, and less economistic way of referring to the complex links/connections between ecosystems and people will be accepted and embraced (see Peterson et al. 2018).

Hence, our statements start from the denial by false of the dichotomy that exists and is made explicit in the conservation literature (see McCauley 2006; cf., Costanza 2006; Marvier et al. 2006; Reid 2006; Arias-Arévalo et al. 2017) between the instrumental and the intrinsic values of nature, commonly called upon to take responsibility for our actions and attitudes towards nature (Martín-López and Montes 2015). There is a huge body of philosophical knowledge associated with the ethical roots of instrumental and intrinsic values (i.e., the former lies on utilitarian/consequential ethics, while the later lies on deontological ethics; see e.g., Norton 2003; O'Neill et al. 2008). Briefly, we understand that the instrumental view of nature is closely associated with a philosophical position known as mechanistic materialism or Cartesianism (philosophical tradition largely adopted within natural scientists community); whether this association is recognized by conservation researchers and practitioners or not. Likewise, the appeal to intrinsic values, ethical and aesthetically, of the natural world is deeply influenced by idealism (see Jonas 1966; Lewontin and Levins 2007). Instead, our philosophical position is anchored in dialectical thinking (e.g., Clark and York 2005; Lewontin and Levins 2007), whose central theses may be summarized as:

> "(…) that nature is contradictory, that there is unity and interpenetration of the seemingly mutually exclusive, and that therefore the main issue for science is the study of that unity and contradiction, rather than the separation of elements, either to reject one or to assign it a relative importance" (Levins and Lewontin 1985, p. 133).

Dialectical thinking is characterized by its systemic and, at the same time, historical point of view. Its premise is, in Marx's words, that '*All that exists, all that lives on land and under water, exists and lives only by some kind of movement. Thus, the movement of history produces social relations; industrial movement gives us industrial products, etc.*' (Marx 1955 [1847], p. 47). In other words, the dialectical thinking seeks to capture a 'moving totality', where each 'part' is in internal relation with the 'whole': each part mediates the whole, and the whole mediates each part. For us, this is how a social-ecological system ultimately works. Dialectical thinking could have deep positive implications for the SES perspective, and also for conservation science, something that has been largely overlooked by researchers and practitioners (but see Norton 2003; Lewontin and Levins 2007; Royle 2017). Dialectical thinking give us the ability to view issues from multiple perspectives (i.e. even in ontological and epistemological terms) and reach the most parsimonious and reasonable reconciliation of seemingly contradictory information and postures (i.e. even paradigms; see Lewontin and Levins 2007). Dialectical thinking is a form of analytical reasoning that pursues knowledge and truth as long as there are questions and conflicts (Lewontin and Levins 2007), as is the case in the conservation of social-ecological systems (Berbés-Blázquez et al. 2016).

Resuming the dialectical understanding of the SES perspective, the non-linear effects, delayed responses, feedback loops and extensive temporal-spatial heterogeneity that characterize a SES (Spangenberg 2011; Cavender-Bares et al. 2015; Maass and Equihua 2015) are purely dialectical logic, something that has not been totally recognized by the *mainstream* discourse yet, partly because it was under a Newtonian logic that we were taught to understand *interactions* (indeed, linear cause-effect relationships are a minority in a SES; see Clark and York 2005; Lewontin and Levins 2007). This is why it is impossible to talk about SES without changing the epistemological and ontological settings (Table 1); and dialectical thinking stands as a path full of tools to solve these philosophical issues (see Royle 2017).

We cannot avoid mentioning here that the implementation of the SES approach for conservation action-research should involve an abandonment of the classical-Cartesian paradigm, or *normal science* (also called *Mode 1 science*, see Gibbons et al. 1994; Kirchhoff et al. 2013 and references therein) in which the mainstream of conservation research has been based (see Table 1 and e.g., Spangenberg 2011; Martín-López and Montes 2015; Ortega Uribe et al. 2014), and is still based with some exceptions (see e.g., Maass and Equihua 2015; Balvanera et al. 2017; Turkelboom et al. 2018).

We claim that the ES concept must be given a new 'reason for being'. First, it has been recognized that there are also services *to* ecosystems (e.g., Huntsinger and Oviedo 2014; Comberti et al. 2015), acknowledging with this the dialectical relationship between social and ecological subsystems (see Clark and York

Table 1. Comparison of the main features of the Cartesian and the SES paradigms. The description and classifications shown in the table are an adaptation of Spangenberg (2011). The characterization of the SES perspective showed here reflects our *philosophically situated* interpretation of it. Some specific references have been selected for each feature in order to further increase the information given and to provide support on each issue. The order of the rows does not imply, in any way, a hierarchy.

Cartesian paradigm (normal and/or Mode 1* science)	SES paradigm (post-normal and/or Mode 2* science)	Selected references
Mono- and multi-disciplinary	Inter- and trans-disciplinary	Spangenberg (2011), Brand and Vadrot (2013); Mauser et al. (2013); Görg et al. (2014); Spangenberg et al. (2015)
Ontological monism	Ontological pluralism	Escobar (2010, 2014); Lombardi and Pérez Ransanz (2011); Spangenberg et al. (2015); Sala (2017)
Epistemological monism	Epistemological pluralism	Norton (2003); Miller et al. (2008); Escobar (2010); Spangenberg et al. (2015)
Centered in equilibrium ideas (static)	Centered in change ideas (dynamic)	Norton (2003); Berkes et al. (2003); Mace (2014)
Trend to generalization and universalization of results (globalized science)	Emphasis on local impact of results (place-based science)	Potschin and Haines-Young (2013); Stewart et al. (2013); Oteros-Rozas et al. (2015); Balvanera et al. (2017); Díaz et al. (2018)
Favors accumulation processes	Favors re-distributive processes	Berkes et al. (2003); Bailey (2006); Carolan (2006); Tallis and Lubchenco (2014); Pouw and Gupta (2017); Zafra-Calvo et al. (2017)
Reductionism and Cartesian analysis	Holism, emergentism and dialectic	Funtowicz and Ravetz (1993); Bergandi and Blandin (1998); Looijen (2000); Carolan (2005); Clark and York (2005)
Highly specialized	Lateral and complex thought	Morin (1996); Scheffer (2014); Scheffer et al. (2015); Sala (2017)
Driven by curiosity and resolution of academic problems	Critical research, driven by society's problems and concrete demands	Funtowicz and Ravetz (1993); Norton (2003); Förster et al. (2015)
Academicist	Academic and social	Funtowicz and Ravetz (1993); Carolan (2006); Spangenberg (2011); Fabinyi et al. (2014)
Peer-reviewed	Extended community peer-reviewed	Funtowicz and Ravetz (1993); Spangenberg (2011); Spangenberg et al. (2015)
Certainty and parsimony (deterministic)	Uncertainty and ignorance (undeterministic)	Funtowicz and Ravetz (1993); Kinzig et al. (2003); Berkes (2007); Polasky et al. (2011); Fernández (2016)
Hierarchical logic	Relational and systemic logic	Norton (2003); Spangenberg (2011)
Scientific proof, unequivocal results	Discursive processes, fallible results, options ranges	Funtowicz and Ravetz (1993); Spangenberg (2011); Spangenberg et al. (2015); Görg et al. (2016)
Liberal/neoliberal value system: competence, efficiency, optimality, selfishness, sexism, etc.	Humanistic/socialist value system: cooperation, altruism, equity, pragmatism, etc.	Fuller (2000); Bailey (2006); Lewontin and Levins (2007); Brockington and Duffy (2010); Büscher et al. (2012); Spangenberg et al. (2015); Brand (2016); Zafra-Calvo et al. (2017)
A *posteriori* ethics	A *priori* ethics	This work; but see Fuller (2000); Nelson and Vucetich (2009); Goldman et al. (2011); Luck et al. (2012)
Science *for* sustainability	Science *of* sustainability	Spangenberg (2011); Ortega Uribe et al. (2014)
Top-down processes	Bottom-up processes	Miller et al. (2011); Spangenberg (2011); Galán et al. (2012); Spangenberg et al. (2015)
Affected *stakeholders*	Involved *stakeholders*	Reed (2008); Galán et al. (2012); Spangenberg et al. (2015); Fernández (2016)
Decision-making with intermediaries/translators	Decision-making without intermediaries (*public policy-ready science*)	This work; but see Bailey (2006), Ascher (2007); Galán et al. (2012); Fernández (2016); Görg et al. (2016); Díaz et al. (2018)

*See Gibbons et al. (1994).

2005; Lewontin and Levins 2007; Royle 2017). Second, the ES concept could positively be used as a way to jump the 'apparent' bridge between social and ecological systems, acting as what some authors call 'boundary concept' (e.g., Schleyer et al. 2017; see below). We say 'apparent' because if, as we assert, there is indeed a dialectical unity between subsystems, then the bridge does not exist as such, but it is erected from the normal (or Mode 1; see Gibbons et al. 1994) science prior to the SES approach (see Spangenberg 2011 and references therein). The ES concept may also be a useful tool to understand that humans need functional and healthy ecosystems in order to maintain adequate and fair ES delivery and supply for present and future generations; provided that decisions on ES are always ethically made, inspired by socio-environmental justice (Funtowicz et al. 1998; Clark and York 2005; Daw et al. 2011; Fabinyi et al. 2014; Bennett et al. 2017; Zafra-Calvo et al. 2017).

However, our proposal is that ES (as a category and as a strategy), should be dialectically contested and analysed, so that they are properly managed, to prevent that the capitalist accumulation system generates for them the same process that occurs with the accumulation of wealth (Dempsey and Robertson 2012; McAfee 2012; Büscher et al. 2012; Gare 2016). It is worth mentioning that monetary valuation of ES is not the only approach available for valuating ES (e.g., Arias-Arévalo et al. 2018), as it is not possible nor desirable to valuate every aspect of ecosystems in monetary terms (see Dempsey and Robertson 2012 and references therein). However, it has been stated that economic valuation can be an 'information tool when not used as a single decision-making criterion', but in the wrong institutional and epistemological setup, it inevitably leads to commodification of nature (Gómez-Baggethun et al. 2010; Gómez-Baggethun and Ruiz-Perez 2011; Dempsey and Robertson 2012; McAfee 2012; Brand and Vadrot 2013; Schröter et al. 2014), an undesirable an reprehensible condition that does not serve neither advocates nor detractors of ES concept (see Martín-López and Montes 2015).

Anchoring social-ecological systems research to conservation science

At present, the pragmatic potential provided by the SES paradigm has been somehow proved, and is accepted by an important part of the sustainability scientists community (e.g., Förster et al. 2015; Oteros-Rozas et al. 2015; Maass et al. 2016; Turner 2016; Balvanera et al. 2017; Mehring et al. 2017). In this sense, the SES perspective emerged as a relatively new knowledge-integrative paradigm that should constitute a shift from *normal science* to *post-normal science* (also called *Mode 2 science*; see Gibbons et al. 1994; Kirchhoff et al. 2013 and references therein; cf.; Funtowicz and Ravetz, 1993; Funtowicz et al. 1998; Carolan 2006; see Table 1). However, the majority of conservation scientists tend to be more reluctant to accept this approach's benefits (see e.g., Kareiva and Marvier 2012; Soulé 2013; Marvier 2014; Kareiva 2014; Wuerthner et al. 2014; cf., Mehring et al. 2017). As a quick overview, the category of post-normal science, introduced for the first time by Funtowicz and Ravetz (1993) arises from the philosophical reading that these authors made of Thomas Kuhn, trying to characterize a new mode of research more appropriate for contemporary conditions (see below). A typical case of these conditions is when there are (a) multiple uncertain factors, (b) values in dispute, (c) the risks are high and (d) urgent decisions must be made. In such circumstances, there is an inversion of the traditional distinction between objective scientific facts (hard) and subjective values (soft) (Funtowicz and Ravetz 1993; Funtowicz et al. 1998). In this sense, place-based transdisciplinary research (Balvanera et al. 2017), strongly associated with the SES perspective (e.g., Brandt 2013; Ortega Uribe et al. 2014; Mehring et al. 2017), is one of the possible knowledge-integrative approaches for doing post-normal science, but there are others such as participatory action-research or responsible research and innovation (Kemmis et al. 2014; see below).

There is much work ahead to make the SES perspective fully operative (but see Martín-López et al. 2017; Mehring et al. 2017), to bring it down from the theory to particular problems (Ortega Uribe et al. 2014; Berbés-Blázquez et al. 2016; Balvanera et al. 2017; Bennett et al. 2017). An extensive body of work regarding land- and sea-scapes conservation and management appealing to the SES approach has been developed around the world (see e.g., Brand and Vadrot 2013 and references therein); but there still are significant knowledge gaps to fill (e.g., Mach et al. 2015; Balvanera et al. 2017; Garcia Rodrigues et al. 2017; and see; Future Earth Implementation Plan 2016–2018). Some of the problems faced in the operationalization of the SES focus are the same all over the world (see Mehring et al. 2017). For example, we are still learning how to deal with the diversity of interests and value systems among stakeholders (Arias-Arévalo et al. 2017, 2018; Pascual et al. 2017), and with those conflicts related to unequal access to ES (Díaz et al. 2011; Oteros-Rozas et al. 2015; Berbés-Blázquez et al. 2016; Maass et al. 2016; but see Díaz et al. 2018). But, besides these conflicts of social nature, there are other extra obstacles of epistemic, traditional and structural nature that delay fully advocation to the SES perspective in conservation science (Table 1; see Mehring et al. 2017).

Scientific tradition has its roots in 'basic science', guided mostly by curiosity and/or by 'what will be published in a high impact international journal' (see Barrere et al. 2014). Although use-inspired basic research, applied sciences, and technologies have been encouraged and are being developed (Clark 2007), most scientific results are rarely straightforward available or easily communicated for decision-makers, requiring extra work from scientists, intermediaries and/or translators (see below and Barrere et al. 2014; Fernández 2016). This is why we stated above that public policy-ready science (PPRS), and not just a policy-relevant science (see e.g., Boyd 2013), is a necessity (Ascher 2007; Vaughan et al. 2007). In this sense, we strongly believe that the SES approach is an important tool towards this goal (see Galán et al. 2012). Under the SES perspective, problem identification and definition are motivated by a concrete social-ecological need (Galán et al. 2012; Spangenberg et al. 2015). Objectives definition and action-research strategies involve every genuine stakeholder, with horizontal, plural, participatory, democratic and respectful working relationships (see Galán et al. 2012; Spangenberg et al. 2015; cf., Carolan 2006). Even more, under the SES approach, scientific and non-scientific knowledge (should) have the same weight, and both are taken into account in the transdisciplinary processes of co-design and decision-making (e.g., Mehring et al. 2012, 2017; Görg et al. 2014). It is expected that a participatory and transdisciplinary approach on these processes (from problem definition to solution implementation and monitoring) would help to put decisions on practice and sustain them in the long term (Carolan 2006; Galán et al. 2012; Mehring et al. 2012, 2017; Spangenberg et al. 2015). Of course, there will be tensions and trade-offs, but this kind of bottom-up processes are demonstrating being useful and effective (see e.g., Palomo et al. 2014; Gelcich et al. 2015; Mastrangelo and Laterra 2015; Turkelboom et al. 2018), what further encourages us to bet for the SES perspective for conservation science.

As already mentioned, we understand that many of the difficulties for the anchoring of the SES approach lie in the academic community itself, that generally holds on to old paradigms and finds it hard to trust in new ones (being sometimes old and new paradigms mutually exclusive, in epistemological terms) (see Moon and Blackman 2014; Ortega Uribe et al. 2014; Maass and Equihua 2015). However, we should not forget that PPRS also depends on what public policy is (see Galán et al. 2012), and how policy structures and processes work (Connelly and Smith 2003). We need to be aware that PPRS also has something to do with the 'policy side of the equation' (i.e., superstructures; see below). While the SES approach might help to overcome the challenges stemming from existing decision-making structures at the local scale; at larger scales policy cycles are much harder to change (Connelly and Smith 2003; see below). Undoubtedly, the State, at its multiple levels (i.e., municipal, provincial, and/or national), is one of the figures that should do its utmost to achieve this 'idealistic' conceptualization of the SES perspective (see Table 1 and e.g., Martín-López et al. 2017), applying to this end all its tools and powers (see below; cf., Bailey 2006).

Last but no least, when talking about research in the SES, it must be mentioned the importance of the Long-Term (Social-) Ecological Research (LT(S)ER) network (see Maass and Equihua 2015; Maass et al. 2016). It has been spreading all over the world since 1980, constituting an international platform (ILTER). LT(S)ER is of extreme importance because socio-environmental problems span wider temporal scales than ordinary research projects; often leaving lines of research unfunded and truncated before meaningful results are achieved. LT(S)ER is not merely a new approach to environmental research, but also a way to help build place-based transdisciplinarity and co-production of knowledge, as well as tools to develop public policies regarding socio-environmental issues (e.g., Maass and Equihua 2015; Maass et al. 2016). We encourage the embracement of such research strategies, as a powerful tool to develop PPRS regarding environmental issues (see Vaughan et al. 2007). However, a network like this would only work with the required institutional infrastructure, coordination among sectors (e.g., academy, management, community, NGOs, etc.), networks of communication, trained staff and, one of the most difficult items in politically and economically unstable peripheral and semi-peripheral countries: long-term financing.

Pushing for the birth of a new paradigm in conservation science

The natural and exact sciences that prevailed in the last nine decades were confined to the Cartesian paradigm of normal science (see Kuhn 1962; Levins and Lewontin 1985; Funtowicz and Ravetz 1993; Lewontin and Levins 2007; Spangenberg 2011; Ortega Uribe et al. 2014; and Table 1), with a *physicalist* profile (i.e., physics as the model of science that all other sciences should emulate), with a strong *dichotomist* imprint, and centred in the use of two powerful tools: *analysis* (i.e., the whole is equal to the sum of its parts) and *reduction* (i.e., in general, it means that superior levels of matter organization can be explained from inferior levels; [see Sala 2017 and references therein]). In this context, the abstraction of the human being from the reality under study was thought to confer objectivity and neutrality to research, but it also obscured the political character of the scientific and technological endeavours (Levins and Lewontin 1985; Funtowicz and Ravetz 1993; Lewontin and Levins 2007; Spangenberg 2011; Kirchhoff et al. 2013).

Thomas Kuhn stated that science makes progress by shifting existing paradigms by new ones, with broader explaining, resolutive, and/or predictive capacity, but this implies a crisis and a subsequent revolution (Kuhn 1962). Our dialectical understanding of the

Kuhn's proposal is that a paradigm is not replaced by its 'mutually exclusive one', but are dialectically 'overcome' (Aufhebung *sensu* Hegel; see above). The current paradigm of normal -and/or Mode 1- science entered a crisis when, among other reasons, action-research related to socio-environmental problems came into the scene (Funtowicz and Ravetz 1993; Gibbons et al. 1994; Funtowicz et al. 1998; Carolan 2006; Kirchhoff et al. 2013). First, an abandonment of reductionism has been lukewarmly proposed by ecosystem-based approaches (Daniels and Walker 1996; Holling and Meffe 1996; Carolan 2005; Levin 2009; Potschin and Haines-Young 2013). To further emphasize the belonging of humankind to ecosystems, the SES paradigm has been pushing to be born. Thanks to the more holistic, plural and, in our view, dialectic nature of the SES perspective, we face the opportunity of embracing a new transdisciplinary way of knowledge co-production and integration, capable of informing management decisions in conservation issues (see Mehring et al. 2012, 2017), as appropriation and re-distribution of ES (or, wider and recent, the NCP; see Díaz et al. 2018), with a broader legitimacy, and socially fairer (Berkes et al. 2003; Pouw and Gupta 2017; Díaz et al. 2018).

Conservation in a capitalist world is certainly a challenge (e.g., Büscher et al. 2012), but we believe that the SES approach has the possibility of reverting the top-down conception of conservation (or, as we like to call it, 'lobby-based' conservation; see Chapin 2004), towards a more participative conservation planning and management. This way, people are actually empowered and appropriate the conservation project under consideration, which leads to better and more legitimate outcomes (Chapin 2004; Carolan 2006; Pouw and Gupta 2017; Zafra-Calvo et al. 2017; Díaz et al. 2018). In this context, it is important to highlight the centrality of the Principle of Subsidiarity as a key concept within the SES place-based transdisciplinary research approach. This is the principle by virtue of which the State executes a work-oriented towards the common goods' management when individuals (i.e., physical and/or legal persons) cannot do it adequately, either by impossibility or for any other reason (Sadeleer 2012). At the same time, this principle requires that the State refrains from intervening when the smallest groups or associations can be self-sufficient (Sadeleer 2012). The Principle of Subsidiarity is applicable in the fields of government, governance, political science, and management of all kinds (see Sadeleer 2012).

We know that the transition to a new conservation science paradigm is not just a matter of will (see Martín-López and Montes 2015; Page 2016). Important and sound structural and epistemic changes are needed, from individual and collective thought structures to institutional setups (see Table 1; Spangenberg 2011; Kirchhoff et al. 2013; Ortega Uribe et al. 2014).

Why public policy-ready science for conservation?

Since the early '70s, where the notion of science-policy interface was incorporated in the academic literature for the first time (see e.g., Cherns et al. 1972; Ripley et al. 1973), a lot has been written about it in order to bring together scientific (and technological) production and the development of public policies aimed at improving the well-being of people and the sustainable functioning of ecosystems (see e.g., Watson 2005; Perrings et al. 2011; Spangenberg 2011; Kirchhoff et al. 2013). In this sense, and mainly over the past 20 years, scholars have been trying to conceptualize what would be the best *model* to handle the science-policy interface (i.e., a conceptual means to simplify and explain the interactions and boundaries of science production and society or policy decision-making), to make it operational and effective (see Kirchhoff et al. 2013 and references therein).

From her influential work, Nowotny (1999) appeals to a decisive shift from the 'reliable knowledge' (derived from the neopositivist or normal -Mode 1- science tradition; Funtowicz and Ravetz 1993; Gibbons et al. 1994; Nowotny 2003; Kirchhoff et al. 2013) towards a more extended notion of scientific knowledge, namely a socially robust -or context-sensitive-knowledge (SRK). There, Helga Nowotny made a call to became aware of a more local, historical and social contingent knowledge production, which would lead to a more SRK (Nowotny 1999, 2003). Socially robust knowledge has three main and interrelated aspects: 1) its validity is tested as well outside as inside the 'laboratory'; 2) it is most likely to be achieved by involving an extended group of experts; and 3) it results from having been repeatedly tested, expanded and modified (Nowotny 1999, 2003).

A second model, which is complementary to the SRK, was proposed by Cash et al. (2003). They suggest to move from the traditional practices of scientists, managers and scholars of science, technology and policy that have been focused on *credibility* (i.e., how to create authoritative, believable, and trusted information), to creating salient/relevant, credible, and legitimate information (i.e., currently known as CRELE; see Heink et al. 2015). The authors propose some mechanisms to mobilize science and technology for sustainability by managing the *boundaries* between knowledge and action in a way that simultaneously improves the salience/relevance, credibility and legitimacy of the information they produce (Cash et al. 2003). For these authors, 1) *credibility* involves the scientific adequacy of the technical evidence and arguments; 2) *salience/relevance* deals with the relevance of the assessment to the needs of decision-makers; and 3) *legitimacy* reflects the perception that the production of information and technology is respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests.

The most interesting thing about this later model is that it incorporates the notions of 'boundary organizations' and 'boundary objects'. The first refers to an organization that facilitates the interaction between science producers and users, and stabilizes the science-policy interface (e.g., Intergovernmental Panel on Climate Change (IPCC), IPBES, etc.); while 'boundary objects' refers to the joint production of models, scenarios, and assessment reports (e.g., climate scenario) by experts and decision- makers. These are collaborative outputs that are *adaptable* to different viewpoints and robust enough to maintain their own identity (Cash et al. 2003; Kirchhoff et al. 2013). Then, effective systems are applied to a variety of institutional mechanisms that facilitate communication, translation and mediation across boundaries (see Cash et al. 2003; Heink et al. 2015).

The models presented above focus on the 'management' of the science-policy interface by introducing alternatives to strengthen that interface (e.g., boundary 'objects' and 'institutions' and/or a new type of knowledge, co-constructed and co-validated by producers and users; see Nowotny 1999, 2003; Cash et al. 2003). Undoubtedly all these measures (or tools) tend to 'narrow' the interface between science and public policies (see Kirchhoff et al. 2013) in general. However, our PPRS proposal explicitly points to the community of conservation scientists, so that from the beginning they (us) address their work, projects and research thinking that their results can -and should- be straightforwardly translated into a public policy, and not just inform it (see e.g., *ROMA: a guide to policy engagement and policy influence*; https://www.odi.org/features/roma/home).

It is not our intention to create a new concept, category or model with the incorporation of PPRS, such as SRK, CRELE, etc. On the contrary, we seek to emphasize and value the *process* by which scientific research may approach as close as possible to the development of public policies. We then started from the diagnosis that the SES perspective -and all its advantages introduced and a critically re-interpreted in this work- is not mainstream in conservation science. Then, one of the ambitious objectives of this paper is to contribute to the mainstreaming of this approach in the field of action-and-reflection of global conservation movement. We see that the SES perspective, still counter-hegemonic in the conservation science (not so in the sustainability science), can become a great catalyst for a new mode of science (more and best) prepared for the generation of public policies related to social-ecological systems conservation and management. In this context, we understand that doing PPRS means following the SES approach (or any other similar) in a critical and situated way (see Table 1). It is necessary to promote practices that enable joint work between researchers, organisations and governments to improve the integration of local knowledge and research-based evidence into policy-making. In this sense, PPRS is more an *idée-force* (a vector) than a category or model classification. Then, any product stemming from a PPRS perspective will be better prepared to follow the designs of the CRELE and will be, necessarily, a SRK.

Last but not least, we know that many colleagues, workers of conservation science, are in effect generating PPRS always that their specific objectives are, e.g., the creation of protected areas based on science, management and/or territorial ordering plans, projects of environmental laws, or participating in panels such as the IPCC or IPBES. We also understand that these practices, when they follow the normal science standards, have more to do with personal commitments than with a systematization of our academic and professional capabilities. This is why in this work we present a critical approach to SES, as an indispensable tool (although not unique; cf., participatory action-research, see e.g., Kemmis et al. 2014) for the development of a science that not only helps to solve the pressing problems faced by our societies, but also fulfils its functions of public value (Kirchhoff et al. 2013).

Conclusions

Since we strongly believe in the potential of SES perspective as a conceptual, methodological and pragmatic tool for conservation science, our intention here was to help its anchoring in the researchers idiosyncrasy, and to encourage a shift inside this academic community towards PPRS (see Vaughan et al. 2007) by providing with philosophical insights (see Norton 2003).

Contrary to the demands of the hegemonic neoliberal model that rules the world-system (and not only the global economy), it is necessary to politicize conservation, which does not means doing it at any cost or in any way (see Goldman et al. 2011). We need the Aristotelian *eudaimonia* (i.e., a fulfilling and fulfilled life) to be our core objective in this politicization (see Rozzi et al. 2015; Gare 2016). An option to this end is to strengthen the formation of transdisciplinary groups in the field of political ecology (e.g., Escobar 2010, 2014; Goldman et al. 2011; Fabinyi et al. 2014).

We would like to finish this work with a brief reflection on ethics. As Norton (2003, p. 457) stated:

> "(…) the idea of sustainability cannot be fully captured in the theories and concepts of any one of the diverse disciplines that contribute to environmental science. In particular, the idea cannot be captured by any science that is understood as an exemplar of objective, descriptive and value-neutral science, whether natural or social. The understanding of science as value neutral, it is now agreed, is at best an abstraction – an ideal that is never achieved by any real science (…) Sustainability

has an inevitable normative aspect, which cannot be fully appreciated unless it is contextualized within an action-oriented situation in which real people compete, conflict, and deliberate about what to do in response to real environmental problems."

We perceive that an unreasonable or uncritical trust has been conferred to technological solutions and/or actual governance models of natural resources (e.g., as a result of a 'proper' management of ecosystem services); and that this attempt against a true sustainability, particularly if we consider 'sustainability' as an emergent property of the SES (Norton 2003; Rozzi et al. 2015). Sustainability is a conscious goal of a teleological system, whereas 'ecological resilience' is a non-teleological emergent property of a natural ecosystem (see Norton 2003; Rozzi et al. 2015). Teleological systems involve ethical issues, whereas non-conscious systems relay in Darwinian fitness aspects (Norton 2003; Rozzi et al. 2015).

Then, could it be that the real obstacle to achieving sustainability is the lack of attention to ethics? This extreme confidence in the advent of the 'expected change' is what we call *a posteriori* ethics (Table 1; see Fuller 2000; Nelson and Vucetich 2009; Rozzi et al. 2015, Gare 2016). It is necessary to develop a new vision of sustainability, more focused on the relational (e.g., Chan et al. 2016; Arias-Arévalo et al. 2017, 2018) or dialectical characteristics between society and the rest of nature (Lewontin and Levins 2007; Nelson and Vucetich 2009). The vast majority of human relationships, either good or bad, involve attitude and action (Varela 1996; Nelson and Vucetich 2009); what is essential in this new view of sustainability is to develop a mature ethical attitude towards nature, and a mature physical relationship with it (i.e., *a priori* ethics; see Table 1). This necessarily involves reviewing our ways of using resources, both individually and collectively (Nelson and Vucetich 2009; Robinson 2011). We share the metaphor of Nelson and Vucetich (2009) in which they affirm that society is like a boat whose engine is technology (in a broad sense) and the rudder *should* be ethics. History and its contingencies testify about shipwrecks caused by technologies that were developed before ethics. In that sense, we consider that, as part of the academic community focused on conservation, management, and/or sustainability science, we are actually doing our best. But we also observe that conservation professionals have unintentionally become experts in palliative cares. In fact, we fulfil the implicit role of a nature 'Band-Aid®' that prevents the world (and all its biodiversity) from a 'mortal bleeding'. Scientific community's eyes and mind should remain wide open to detect the root causes of socio-environmental problems, to stop our Mother Earth (and all its inhabitants) from suffering. Will not it be time for scientists to become also policy-makers? Our urgent response would be: why not.

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