Biological Conservation 238 (2019) 108228

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Evaluating transdisciplinary science to open research-implementation spaces in European social-ecological systems

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ARTICLE INFO

Keywords:
Assessment
Evaluation
LTER
LTSER
Social-ecological
Transdisciplinary

ABSTRACT

Researchers in multiple, related fields that address complex social and environmental challenges, have shown ongoing enthusiasm for applying transdisciplinary social-ecological systems (SES) research to promote sustainability. However, few studies have evaluated the effectiveness of SES approach, assessed its achievements, and identified challenges to its implementation toward knowledge production for environmental conservation.

We report the results of a qualitative, participatory evaluation of several SES projects across Europe using an evaluation methodology tailored to transdisciplinary projects. We conducted 66 stakeholder interviews at four designated Long-Term Socio-ecological Research (LTSER) platforms – Danube Delta and Braila Island (Romania); Cairngorms (Scotland); and Doñana (Spain). Using qualitative analysis, we synthesized data from interviews and then returned to the sites to present findings to stakeholders in focus group discussions in order to incorporate their feedback into conclusions.

We conclude that although particular scientists at each platform have taken on entrepreneurial roles to operationalize transdisciplinary science, a business-as-usual attitude tends to dominate institutions, limiting meaningful progress toward transdisciplinary objectives, including: integration of social science research, giving non-researcher stakeholders a more meaningful role in advancing relevant research, and improving knowledge exchange among different stakeholder groups, among other issues. While we found that all the components of transdisciplinary SES research exist at the sites, there is no overarching strategy to link long-term planning and funding, knowledge integration, and priority-setting with stakeholders to ensure the relevance of research for policy and practice. We conclude with reflections about implementing our evaluation methodology, and a call for periodic, participatory evaluation into the future.

1. Introduction

The integrated study of social-ecological systems (SES) aims to understand the complex relationships between the environment, ecosystems, natural resources and human influences in a systemic way (Berkes and Folke, 1998). It has been applied by scholars, research networks, and funders, in support of their goals to understand and advance sustainability, most notably in the fields of resilience thinking (see, e.g., Colding and Barthel, 2019; Carpenter et al., 2012) and social ecology (see, e.g., Hummel et al., 2017a; Fischer-Kowalski and Weisz, 2016). The SES approach is interdisciplinary, promotes public involvement, and is increasingly taking a more explicit transdisciplinary stance (Angelstam et al., 2018; Holzer et al., 2018a; Hummel et al., 2017a; Lang et al., 2012; Baumgärtner et al., 2008). A transdisciplinary approach, by definition, integrates fields beyond academia with academic research, and engages stakeholders in knowledge co-production, through processes of collective inquiry and reflection with relevant stakeholders (Lang et al., 2012). Used to address complex societal problems across several areas including environmental sustainability, natural resource management, and public health (Polk, 2014), transdisciplinarity transcends any single field or approach by promoting the synthesis of different types of knowledge. It seeks to develop a practical, contextual, self-aware understanding that may be applied to addressing the complex and uncertain challenges that arise in complex SES. At the

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https://doi.org/10.1016/j.biocon.2019.108228
Received 26 March 2019; Received in revised form 5 August 2019; Accepted 27 August 2019
Available online 24 October 2019

practical level, it constitutes a key approach for creating the knowledge, skills, and collaborations necessary among researchers, practitioners and stakeholders for furthering sustainability (Brandt et al., 2013; Carew and Wickson, 2010; Polk and Knutsson, 2008).

However, the implementation of transdisciplinary SES research approaches face two main challenges that we address in this article: complexity and translation of research outputs to societal impact. As for the first challenge, the implementation of transdisciplinary SES research approaches can be as complex as the SES to which it is applied; in part, due to the cyclical, iterative, contextual, and synergistic nature of the process (Toomey et al., 2017; Hauck et al., 2014; Mauser et al., 2013). The approach also requires a special skill set (e.g. adept facilitation, leadership, teamwork, and ability to synthesize data and knowledge) to work with different stakeholders to co-design, co-produce and co-disseminate (sensu Mauser et al., 2013) knowledge that spans multiple disciplines and fields of experience. Because of its complexity, conducting an efficient and useful evaluation of transdisciplinary knowledge production is particularly challenging (Holzer et al., 2018a; Walter et al., 2007). Some methods have been developed to evaluate transdisciplinary research (e.g. Pohl et al., 2011; Klein, 2008; Spaapen et al., 2007; Bergmann et al., 2005), which mostly focus on process evaluation and provide outputs that are limited in actionability. Although there have been more than two decades of experience implementing SES research, there is a deficit of performance evaluations for understanding how such programs are contributing to society (although such studies are slowly emerging, e.g. Carr et al., 2018; Siew et al., 2016; Frescoln and Arbuckle Jr, 2015).

Regarding the second challenge, the implementation of transdisciplinary research approaches faces the challenging divide between science and action (Fig. 1). Known in conservation science (Knight et al., 2008; Hulme, 2014) and SES research (Nuno et al., 2014), as the "research-implementation gap" (RIG), this divide refers generally to the challenges of applying scientific knowledge to address societal challenges in environmental sustainability (Bertuol-Garcia et al., 2018). Closing the RIG is made difficult by entrenched social and institutional factors – deficient communication and lack of long-term commitments between researchers and practitioners, challenging institutional and governance settings, poor political and financial support, and the weak consideration given to social dimensions and transdisciplinary research (Mair et al., 2018; Arlettaz et al., 2010; Knight et al., 2008). However, recent perspectives have identified a series of weaknesses in how we understand and frame the RIG vis-à-vis implementation; they argue for a reframing that is more creative in resolving current social, institutional and epistemological challenges, and which better considers the social context in which conservation is studied and implemented (Toomey et al., 2017). For Toomey et al. (2017), reframing the RIG as a "research-implementation space" (RIS) emphasizes features and dimensions of this divide (e.g., values, ethics, attitudes, institutions, interpersonal dynamics) (Fig. 2) that can be more useful for addressing value conflicts and complex relations between researchers and practitioners, as well as missing aspects of transdisciplinarity (Toomey et al., 2017). RIS connotes the area of interaction in which research and action occur simultaneously and continuously influence one another and, more than just "filling the gap," these interactive processes are sensitive to their socio-cultural and political context (Toomey et al., 2017). Within the RIS, inter- and transdisciplinary approaches collapse the dichotomy between researchers and practitioners and consider the diversity of stakeholders' perspectives and interests by returning the focus to the real-world problems being addressed (Buschke et al., 2019; Mauser et al., 2013). Ultimately, it embodies what is feasible in political, administrative and ecological terms, in an integrated way (Buschke et al., 2019).

To address these challenges, we developed a customized evaluation framework (based on Holzer et al., 2018a) (Fig. 3) and tested it in the European regional network of the International Long-Term Ecological Research (ILTER) network. ILTER is a global environmental research infrastructure, set up to help understand and address global grand challenges such as climate change, biodiversity loss, eutrophication, and pollution (Mirtl et al., 2018). The European LTER sub-network has designated study regions, known as "Long-Term Socio-Ecological Research (LTSER) platforms," as an effort to establish long-term SES research approaches, sustained public involvement, and place-based and socio-economic observations and variables that can contribute directly to solving global environmental challenges (Mirtl et al., 2018; Maass and Equihua, 2015). While many research projects conducted via LTSER platforms take the conventional one-way approach in which science informs policy and implementation, there is growing recognition in the ILTER network, as in the study of SES more widely, of the need for participatory science in which the scientific agenda is co-created and research co-produced together with stakeholders – especially among scientists collaborating on SES projects (e.g. Carmen et al., 2018; Dick et al., 2018a). We tested our evaluation framework in four European LTSER platforms, including an analysis of perceptions of existing RIGs and opportunities for the creation of RISs by stakeholders and an inquiry into stakeholder roles and perceptions about transdisciplinary SES research in their region.

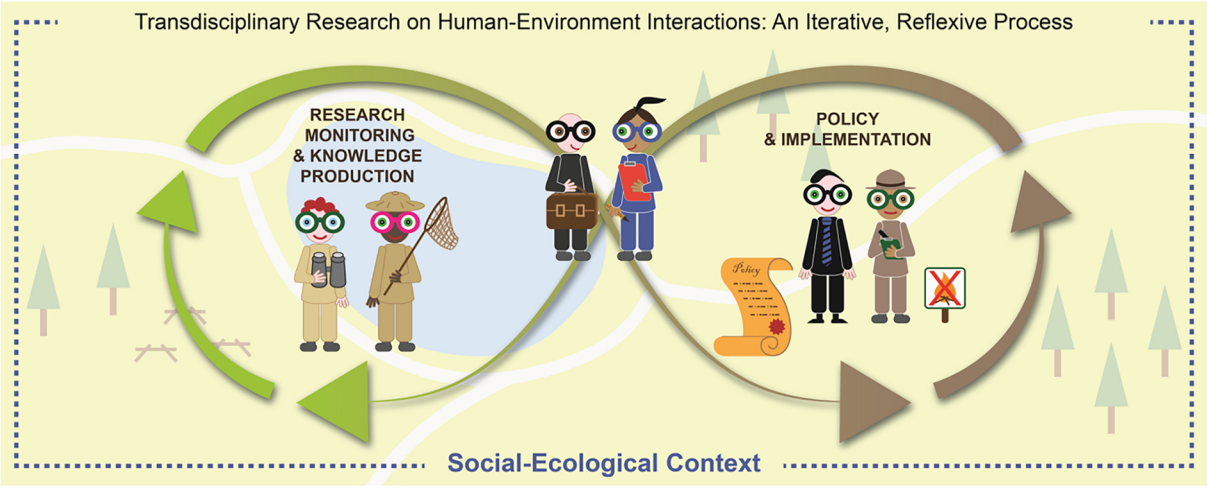

Fig. 1. A conceptual model of transdisciplinary research on human-environment interactions, the focus of SES research within the global ILTER research network. Interlocking processes of knowledge production and policy and implementation work in tandem, relying on continuous feedbacks. This constitutes a participatory process that is iterative, adaptive, and self-aware, and is punctuated by periodic evaluation, which feeds back into both processes. Credit: Ronit Cohen-Seffer.

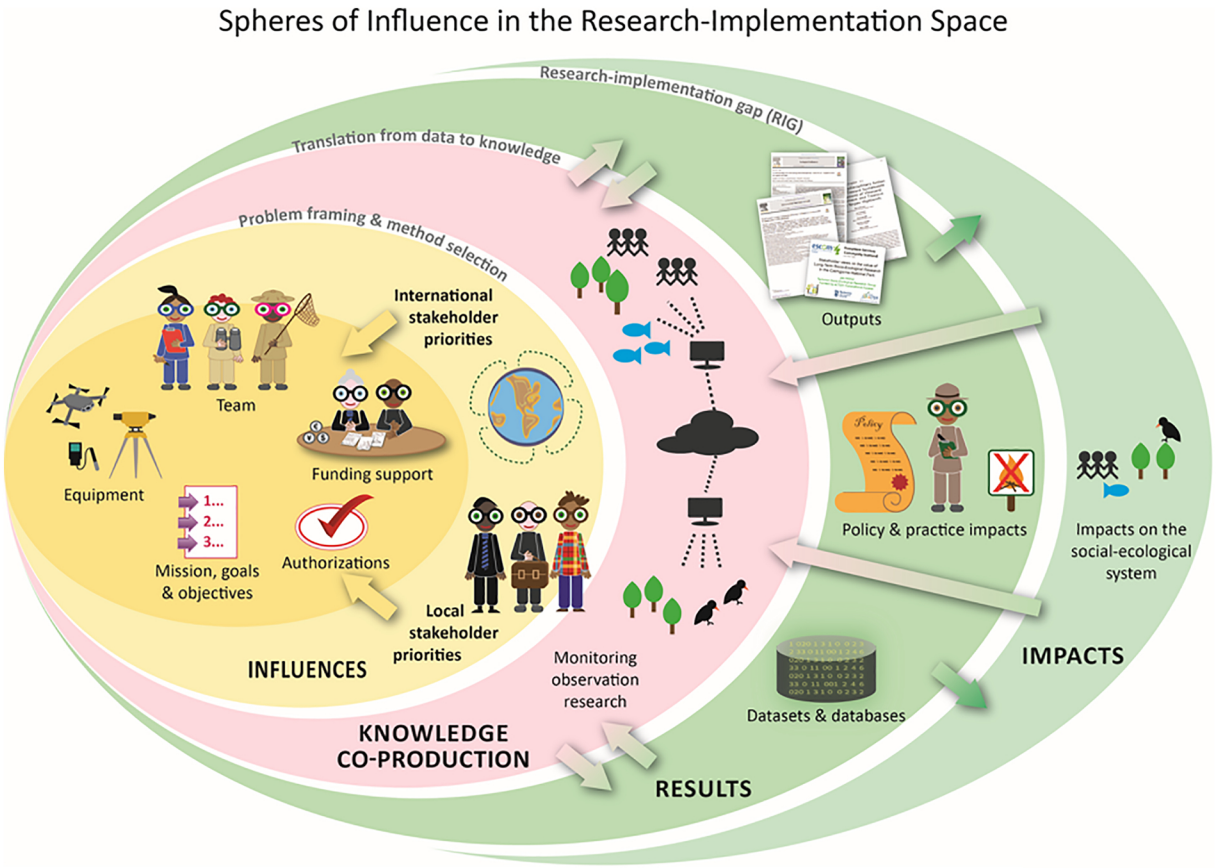

Fig. 2. Schematic of the interacting influences of stakeholders, knowledge production processes, policy and practice, and their impacts on the social-ecological system. The entire system functions as a 'research-implementation space'. Credit: Ronit Cohen-Seffer.

In general, we sought to understand if/how the elements of transdisciplinarity are present in SES research programs at the case study LTSER platforms, and whether these research programs are perceived to be growing their capacities for improved science-based knowledge exchange, decision-making, policy and practice. Our overarching question was whether substantive changes in conducting research are occurring that could corroborate the idea that a paradigm shift is taking place among scholars who are adopting a more policy-oriented, applied research approach to address urgent challenges to ecological integrity and environmental sustainability, as others have suggested (Dick et al., 2018a, 2018b; Teel et al., 2018; Enquist et al., 2017; Singh et al., 2012; Haberl et al., 2006). Additionally, by collecting qualitative data about projects that aim to exemplify such a paradigm shift, we articulated the goals, achievements, and challenges of SES research. In doing so, we assess and characterize it within the European LTER and global ILTER networks.

2. Methods

2.1. Method overview

Our method was based on a flexible design consisting of six steps (Fig. 3), each of which informed and contributed to the subsequent step. We began by conducting a literature review of transdisciplinary research theory and evaluation methods. Then we constructed an evaluation framework specifically designed for transdisciplinary research projects (Holzer et al., 2018a). Next, we selected four LTSER platforms from the European LTER network, based on a series of pre-established criteria (see Section 2.3). Using the evaluation framework, we interviewed multiple stakeholders to learn their perceptions of existing RIGs, including researchers, land managers, environmental advocates, and other local actors, regarding their roles and perceptions about SES research in their region. We then analyzed those interviews for where RISs might be defined, and presented our interim results to stakeholders in focus groups at each study site, recorded their responses, and used this information to validate or adjust our interim results. Finally, we carried out a comparison of the transdisciplinary work performed across the four platforms, whose results are presented below.

2.2. Theoretical approach

We used a qualitative approach to research, inspired by grounded theory (Glaser and Strauss, 1967). Its core method is based on in-depth interviews, with no predefined hypotheses about the phenomena under study, thus allowing for inference from interviews (i.e. deductively) (Creswell and Creswell, 2017). The interviewer asks open questions of a range of actors, in order to understand which environmental issues were most important to them and which elements of the social-ecological environment were most relevant for them (Millerand et al., 2013; Lingard et al., 2008). In the field of conservation research, interviews have been found to be a flexible method that can produce high quality data on complex issues, including decision-making processes (Young et al., 2018).

2.3. Selection process for case studies and interview protocol validation (Stage I)

The four LTSER platforms evaluated as case studies within the Europe-LTER network fulfilled the following criteria. They: (1) operated officially as LTSER platforms for at least five years; (2) were

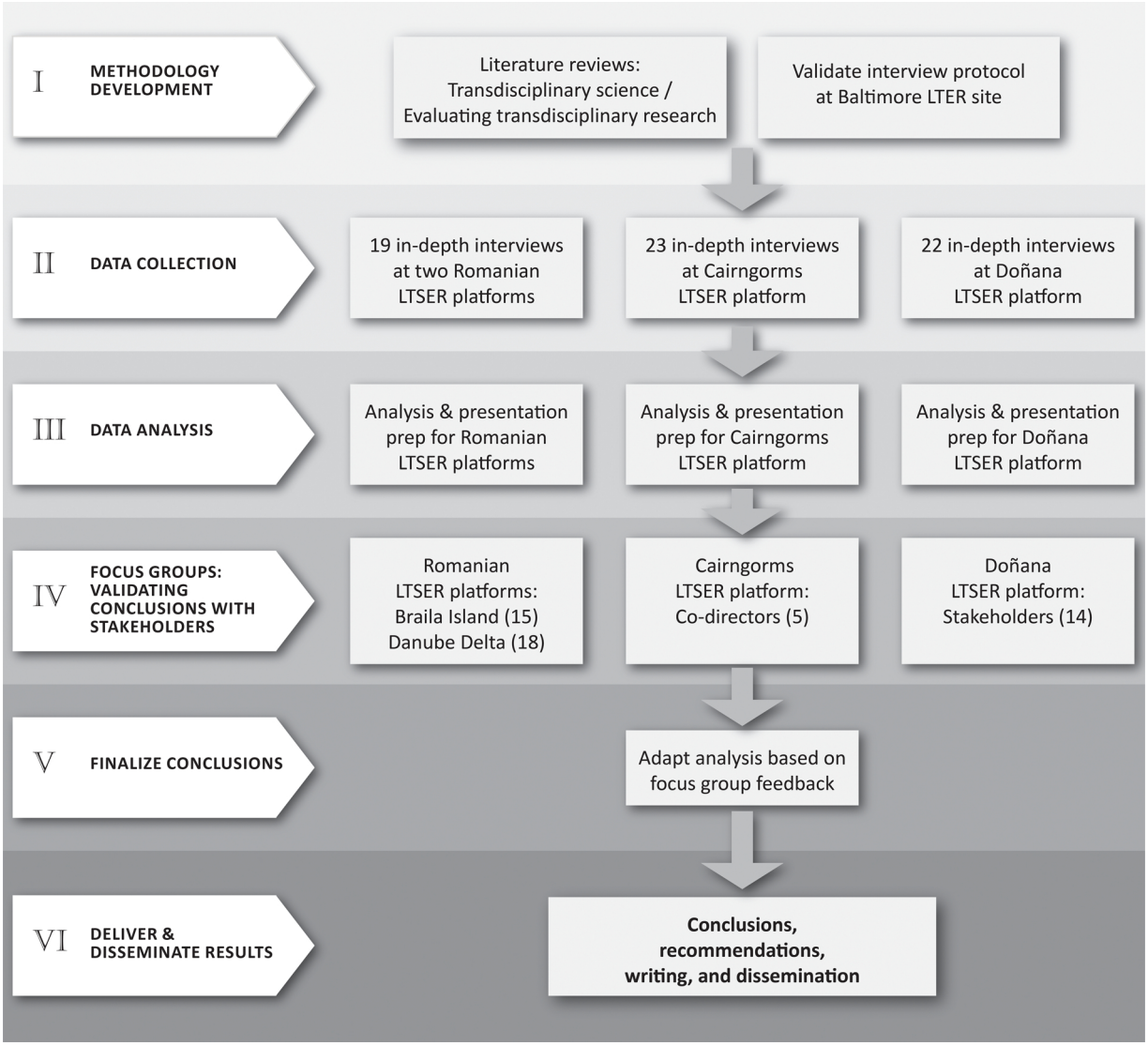

Fig. 3. Flow chart illustrating the research. Numbers at stage IV indicate the number of individuals who participated at each focus group. Credit: Ronit Cohen-Seffer.

actively conducting both ecological and social research, engaging stakeholders in research, and had recently published papers on both ecological and social subjects; and (3) fulfilled practical criteria (e.g., on-the-ground logistics to host research visits and assist in data collection). Platform case studies included: Danube Delta LTSER and Braila Island LTSER, Romania; Doñana LTSER, Spain; and Cairngorms LTSER, UK.

As a preliminary step, the interview protocol was validated by conducting interviews with several natural and social scientists and stakeholders at the Baltimore Ecosystem Study, an LTER platform committed to social-ecological research in Baltimore, Maryland, USA. This site has conceptualized a well-developed arc from research to decision-making, and is active in the international LTSER community (Grove and Pickett, 2019).

2.4. Data collection (Stage II)

Two data collection trips were made to each case study region – first, to conduct interviews, and later, to conduct focus groups. Host researchers (listed in Appendix I) coordinated interviews with researchers from their research institutions, government-supported and independent research institutes, park managers, local government officials, and other stakeholders (NGOs, business representatives) at LTSER platforms (see Appendix I for list of interviewees). Host researchers, as leaders of their LTSER platforms, were themselves interviewed by the primary author. This was done in the interest of knowledge co-production, where host researchers, as stakeholders in this research evaluation, participated in data collection and contributed feedback to the analysis. To avoid conflicts of interest and ensure consistency, however, full data analysis and conclusions were drawn primarily by the first author.

We strove to conduct about twenty interviews in each platform, a number that we deemed sufficient through ongoing reflection during the data collection process (Sim et al., 2018). Hosts helped to tailor initial lists of key stakeholders, and from that list, we continued recruiting respondents until we reached a representative and sufficient sample from which to draw conclusions for each platform and for extrapolating to the broader LTSER network (Sim et al., 2018). Additional detail about representativeness of the interview population sample is given in Appendix II.

All interviews were digitally recorded, transcribed verbatim and imported into Atlas.ti, a Computer-Assisted Qualitative Data Analysis (CAQDAS) software, for data analysis. This tool was used to upload interview transcripts, highlight codes, and more easily categorize and search codes and supporting quotations.

2.5. Data analysis (Stage III)

Coding is typically an iterative process of briefly paraphrasing noteworthy segments of interviews using a word or phrase, until these "codes" reach a saturation point (Saldaña, 2015). We used "conventional content analysis," an inductive process used to generate codes from interview data (Hsieh and Shannon, 2005). These codes are then used to categorize the information from interviews and focus groups, a process called "directed content analysis". The next step is to refine and narrow codes, to remove duplicates, and to group similar codes, a process called "axial coding," which combines the inductive and deductive processes. These code groups are titled; these titles essentially constitute the themes of the interview analysis. This was the process followed to analyze interview data.

Interviews were read and coded by the primary author. After coding, a *reviewer validation* process was carried out, described in detail in Appendix II.

A *code group validation* exercise was then performed to check the logic used to group codes, and is also detailed in Appendix II. This process helped the primary author clarify her thinking about code groupings, and the volunteers gave several ideas for nesting code groups. Overall, we estimate that this process resulted in less than a 15% change in coding organization.

However, the validated code groups still constituted more data than could be both directly relevant to the research questions and easily synthesized (see Appendix III for full listing). Many of the codes described site-specific issues or specific social-ecological challenges and were therefore not relevant to this study, which sought to understand general trends across entire research platforms. To account for this, we decided to retain only high-frequency codes (i.e. codes that were repeated 10 times or more); this gave a total of 31 codes, which were clustered into nine code groups (Appendix II).

2.6. Focus groups: validating conclusions with stakeholders (Stage IV)

Because our aim was to deliver a useful and actionable evaluation to the LTSER community of researchers and partners, we included a participatory validation of conclusions in our evaluation. Return visits were made to each site and preliminary conclusions were presented. This took the form of a 45-minute presentation that included generalized conclusions about all the cases as well as platform-specific conclusions. At the end of the presentation, participants were asked to respond, react, and critique the presentation content.

Participants at these meetings represented similar stakeholder groups as represented by the interviewees, including scientists and land managers. In all cases, some focus group participants had been interviewed, but most had not. See Appendix III for further detail.

Meetings were audio-recorded, transcribed, and used as a reference while finalizing conclusions.

2.7. Finalize conclusions (Stage V)

Recordings and notes from focus groups were used to supplement and, in some cases, adapt, initial conclusions, thus putting a "check" on the data analysis process, and incorporating focus group data into the final analysis. The first author used the following questions to guide the process of adapting conclusions: 1) Did focus group participants disagree with or object to any part of the presentation? 2) Which subjects did participants emphasize (either in terms of time dedicated to a subject, or intensity of expression) during discussions? 3) Did focus group participants articulate specific insights or subjects that were of particular interest/importance to them?

2.8. Deliver and disseminate results (Stage VI)

Following best practices of transdisciplinary research, we have emphasized the importance of knowledge exchange, of which this paper is meant to be an example. We chose to share and discuss results in focus groups, and to present this article to colleagues in the hope of provoking reflection and discussion that can lead to concrete improvements in the research process at the study case platforms and among their peers. Observations and conclusions will also be integrated into LTSER best practice guidelines, now in preparation, for the LTER-Europe network.[1]

3. Results and discussion

Rich and abundant insights were derived from this study about progress made in advancing SES research for shared understanding and decision-making. We present these results as several themes drawn from a combination of content analysis and field observations during interviews (Stage II; Fig. 3) and return-visit focus groups (Stage IV; Fig. 3), each accompanied by an explanation and key supporting observations. Following these themes, we note the influence of local context and reflect upon the efficacy of our assessment method as well as its failures. We include a table of recommendations for SES research platforms based on our findings. Finally, we share site-specific narratives about each of the case studies (see Appendix V: Box 1, Box 2, Box 3) before drawing final conclusions.

3.1. Social research is being integrated slowly and reluctantly into ecological research programs

LTSER platforms were initiated primarily by natural scientists who supported the idea of integrating other disciplinary perspectives in applied environmental research. The degree to which additional social research has been integrated into these LTSER platforms, however, is low. In some cases, there is high-quality social science research being conducted that focuses on the site, but it is not affiliated with the LTSER platform.

Many interviewees referred to socio-economic, demographic, and geographic research that they believed would help to better understand human activities and their environmental implications. Special mention was made regarding research collecting local knowledge, such as the knowledge of elders who remember details about the environment and natural resource use practices from before protected areas were established, as well as historical and archival research, which is considered by some to be a valuable, untapped resource.

Literature suggests that ongoing interdisciplinary and transdisciplinary collaboration, such as that required to integrate social and ecological sciences in a research program, often requires incentives (Shanley and López, 2009; Stokols et al., 2008). We observed that the research institutions affiliated with the LTSER platforms in this case study did not incentivize social science research, nor did they integrate transdisciplinary science generally or SES research in particular into their missions.

Key observations:

- Social science research has been conducted on an ad hoc basis, and then usually because funding has been designated or mandated for social research (e.g. Dick et al., 2018b; Carmen et al., 2018; Dick et al., 2017).
- No formal social science monitoring has been initiated by platform-affiliated scientists.

[1] Orenstein, DE, Angelstam, P, Dick, J, Holzer, J, Sijtsma, F. (2019). Long-term socio-ecological research platforms: A best practices guide book. Deliverable 10.3 of European Union Horizon 2020 Grant Number 654359 "European Long-Term Ecosystem and Socio-Ecological Research Infrastructure—eLTER".

- Lead scientists set the tone for the research program. When a lead platform researcher associates their professional identity with integrative science, social science elements are more often included in the projects. Conversely, researchers who more readily define themselves as disciplinary scientists were less involved in cross-disciplinary activities.

3.2. Non-scientists are generally invited to participate when required by funding sources, when projects are already in process

Since transdisciplinary, social-ecological science is meant to integrate knowledge, incorporate differing values of diverse stakeholders, and create a sense of ownership to improve problem-solving, the meaningful inclusion of stakeholders in setting the research agenda, conducting research, exchanging knowledge, and contributing to problem-solving processes is widely acknowledged (Lang et al., 2012; Pohl et al., 2011). We found that researchers did not usually consider themselves stakeholders. Rather, they used the term to refer to environmental managers, NGOs, business interests, and local residents of the LTSER platforms. These stakeholders were included in the research process when mandated by a project (usually to comply with funding requirements), and brought into the project after it had been designed and begun by scientists, in contrast to what has sometimes been called the ideal situation in transdisciplinary research, of setting priorities, objectives, and methods together with stakeholders in advance of beginning a research endeavor (e.g. Lang et al., 2012; Pohl et al., 2011). Scientists were acutely aware of local controversies and diverse points of view, but without explicit funding for inclusion of non-scientists in a project, non-scientists were rarely consulted.

Key observations:

- Researchers usually reached out to stakeholders using a snowball approach. While this may often be appropriate, it highlighted a lack of methodological diversity that may indicate a lack of expertise and/or experience regarding conducting social science research.
- Despite the centrality of stakeholder participation in transdisciplinary theory (e.g. Scholz and Steiner, 2015; Lang et al., 2012), no procedure or criteria were in place to determine when stakeholder participation would provide added value to a project, nor were there accepted guidelines for conducting stakeholder participation exercises.
- Some researchers did not perceive the stakeholder participation process as valuable, certainly not as valuable as consultation with experts. A related topic, maintaining ongoing relationships with end-users and local residents, was emphasized as important by some scientists (e.g. Canova et al., 2019).
- Many researchers were aware of "stakeholder fatigue," (Reed, 2008) and attempts were made to "lump" meetings for separate projects on the same day to respect stakeholders' time.

3.3. Research priorities are strongly influenced by donors, scientific institutions and administrative factors

In general, research priorities are driven by available funding, institutional priorities (which are often rigid), staff capacity and resources. Interviewees reported few institutional or funding changes since the establishment of their respective platforms, but researchers advocated the goals of SES research and used research grants to advance these aims whenever possible. Three platforms were led by natural scientists who led initiatives related to social science, policy, and stakeholder relations (Cairngorms; Braila Island; Danube Delta). At the fourth platform, EU-supported project funding enabled the recruitment of a dedicated researcher to take the lead on SES research and stakeholder participation (Doñana). However, despite these aims being clearly conceptualized in the minds of these "platform champions"[2] and a few of their closest colleagues, the degree to which the priorities of transdisciplinary, SES research has been integrated into the research strategy and plans of local institutions has been limited to date. However, interviewees suggested that they perceived a trend toward transdisciplinarity to be slowly growing.

Difficulties with funding were exacerbated beyond the typical challenges because of the dilemma of maintaining existing lines of long-term research while also adding SES research, or what has been called an add-on "to an already defined agenda" (Stone-Jovicich et al., 2018). The aspiration of maintaining ongoing environmental and social monitoring programs also presents a problem for short funding cycles (typically 2–5 years), which are particularly difficult to align with the objectives of a network of long-term research platforms (typically 20–50 years).

Key observations:

- In some instances, researchers with a transdisciplinary orientation played the role of mediators between other stakeholders who viewed scientists as credibly unbiased (Barnaud et al., 2018).
- While researchers often recognize how highly influenced the RIS is by socio-cultural and political processes (Avriel-Avni and Dick, 2019), they may not feel that it is legitimate to discuss these contextual issues in their role as scientists.
- A Cairngorms researcher believed that her affiliation to the LTER-Europe network helped her to win a large research grant that was used to advance compatible goals (Holzer et al., 2018b; Jax et al., 2018).
- Few changes were made by local institutions in providing additional human resources or training; however, scientists sometimes attended trainings through LTER-Europe workshops and obligatory meetings for EU-funded projects.
- *Counter-example*: An exception to the lack of unified research goals by researchers and environmental managers was exemplified by the Research Strategy, adopted in 2012 by the Cairngorms National Park Authority (CNPA). This document aimed to integrate and guide all research conducted in the national park providing an overview and specific research themes. When a new director of the CNPA was installed, he questioned the Research Strategy and, in consultation with park authority staff and local residents, proposed revising it to include detailed specifications of new desired research, which could be used directly to solicit new research projects.

3.4. Researchers are disappointed at low level of sharing of scientific knowledge with non-scientist stakeholders

Many of the researchers interviewed expressed disappointment that their research findings often only reached other scientists and not other types of stakeholders. Several scientists observed the difficulty of sharing knowledge with non-scientists when their professional value is, in large part, measured by the scientific articles they produce.

Scientists reported in interviews that part of their motivation for sharing their research with non-scientists was the belief that if non-scientist stakeholders understood the science underpinning the social-ecological system, they would convert to the same beliefs as the scientists about what actions should be taken. However, this is not supported by recent research, which suggests that such a direct link between environmental education and behavior change is often an

[2] We employ the term "platform champion" in the sense of *sustainability champion,* an epithet used by some scholars to describe leadership in contexts of universities and private enterprises, (Wood et al., 2016; Wiesner et al., 2011; Willard, 2009) but which has not, to our knowledge, been applied specifically to researchers advocating changes to a research infrastructure.

oversimplification (Hargreaves, 2011). Recent research has highlighted differences in worldviews between researchers and land managers (Avriel-Avni and Dick, 2019; Hummel et al., 2017b).

Overall, although a transdisciplinarity RIS aims for co-production of knowledge – knowledge produced collaboratively with stakeholders – and multi-directional knowledge exchange that values different types of knowledge (e.g. scientific, practical, experiential), we only rarely saw evidence of these concepts in practice. On the other hand, knowledge exchange events were implemented in some cases. Two platforms held regular knowledge exchange events that helped to disseminate current research findings to environmental managers and other stakeholders. The Doñana Protected Area Administration staff holds regular lunch-time research talks and the Cairngorms LTSER organizes a bi-annual conference to share knowledge about Cairngorms National Park across sectors.

All case platforms discussed the importance of maintaining publicly accessible databases of platform-based research projects. At Doñana, such a list does exist (http://icts.ebd.csic.es/en/current-projects), together with a system of access to monitoring data (http://icts.ebd.csic.es/en/monitoring-program). There was also a publicly-available list at the Cairngorms platform, although it had not been recently updated, which has now obtained funding to conduct a literature review that would advance previous work cataloguing and describing Cairngorms-related research (Dick et al., 2018a). In general, the issue of who would be responsible for maintaining and updating such databases was an elusive problem. In some cases, a designated body was responsible (e.g. the Doñana Biological Station (EBD-CSIC) has a legal mandate to coordinate all the research taking place in the Doñana Protected Area). Researchers also discussed non-exsistance, or lack of access to, geodatabases with spatial data, whose availability was often dependent on funding for a dedicated staff person.

Key observations:

- Many academic interviewees expressed a desire for research findings to be condensed into more user-friendly materials that could be distributed to stakeholders, and would be more accessible than scientific articles.
- All platforms contributed their data to the LTER-Europe metadata base for LTER and LTSER platforms (DEIMS: https://deims.org/).
- Some stakeholders (two scientists and one attorney who previously sat on Doñana National Park Participation Council) created personal "science communication" projects like blogs and children's books to educate the public about special and changing aspects of park ecology and management.[3]

3.5. Although research does influence environmental management, it cannot be attributed to a transdisciplinary turn

Research at LTSER platforms sometimes includes work like environmental impact assessments (Doñana), sustainable management plans (Braila Island), and direct support of conservation goals, like woodland expansion to meet national targets (Cairngorms), the setting of fish catch allowance limits (Danube Delta), or research on the effects of electric towers on nesting eagle populations (Doñana). These activities are not necessarily coordinated with multiple stakeholders or with the LTSER platform; they are in line with conventional conservation biology, applied ecology and legal requirements (e.g., public participation) and, although they do affect the social-ecological system on the ground, they are not necessarily a result of transdisciplinary SES research.

Key observations:

- An unanticipated impact of the platforms, described by two Doñana conservationist interviewees, was "research tourism," the phenomenon of research projects bringing scientists in greater numbers to the Park, and the fact that their activities, like setting up plots and driving vehicles across the Park, have environmental impacts on a protected area whose use is limited to researchers and national park rangers (Appendix V: Box 1). The phenomenon of ecological impacts of ecological research within protected areas has been noted previously; the World Commission on Protected Areas has drafted a code of ethics to mitigate this issue (Hockings et al., 2013).
- Several interviewees observed that a lack of clear environmental management objectives for Doñana National Park created obstacles to building a relevant research program. This fact not only creates a challenging situation for stakeholder communication, it also makes it more difficult for scientists to prioritize research goals, and makes it nearly impossible to assess success of conservation measures.

3.6. The value of research platforms depends significantly on international network resources

The establishment of LTSER platforms can be considered a formal declaration of intent toward integrating SES research and monitoring relevant for policy making. Each platform benefits from the ability of the network to advocate for them, and to create opportunities for tapping into funding, data-sharing, knowledge exchange and an intellectually-diverse epistemic community (Holzer et al., 2018b; Chilvers, 2008). Researchers particularly valued the global ILTER community of colleagues and land managers and appreciated recognition of the network by the EU and other international institutions.

Some interviewees expressed the view that the growing popularity of the LTSER concept and the conversations it fosters constitute added value. In particular, some expressed the hope that advancing research topics related to ILTER's "grand challenges" – such as understanding ecological carrying capacities and tipping points – could advance the relevance of research for policy making.

EU funding and networking has special importance for platforms in countries whose unclear and frequent changes of legislation, as well as weaknesses in law enforcement, make scientific research programs volatile and uncertain (see Appendix V: Box 2). EU funding, of course, also provides the benefit of consistency of methods and approaches across countries and geographies. Interviewees from platforms located in countries that democratized later and experience greater challenges enforcing environmental regulations (O'Brien, 2015) also pointed out the importance of EU for maintaining environmental standards at the local/regional scale (e.g. Romania, Spain).

Key observations:

- Some protected area managers valued the multiple international designations conferred upon their respective protected areas (e.g. Ramsar sites, biosphere reserves, UNESCO World Heritage Sites, LTER sites, LTSER platforms); others couldn't articulate their value.
- Discussions mentioned how different designations are valuable for different types of stakeholders. For example, LTER and LTSER, despite their transdisciplinary aspirations, remain primarily research infrastructures and researchers are their primary advocates.

3.7. Key challenges to platform development are rooted in shortcomings in communication and management

A major challenge of the LTSER platform is in defining its mission and objectives at the local level, and clearly communicating that vision to partners and potential end-users. As mentioned above, while platform champions often succeed in conveying their platform vision to

[3] e.g. Blog of the late Jesús Vozmediano y Gómez-Feu: http://jvozmediano.blogspot.com; blog of LAST-EBD Remote Sensing & GIS Lab: http://last-ebd.blogspot.com.

close colleagues, the message does not necessary travel more widely (see Appendix V: Box 3).

While such issues are not unique to SES research, interviewees reported lack of trust among stakeholders for reasons including: competition between researchers, epistemic rifts between natural and social scientists, and local, socio-political conflicts (see Appendix V: Box 2). Rifts between scientists, decision-makers and local stakeholders – observed in the way some researchers had a patronizing attitude toward stakeholder participation activities – might indicate a gap in expertise in science communication, stakeholder relations, and science-policy interface, and a lack of awareness or adoption of the RIS conceptualization of doing science.

Key observations:

- While platform champions appeared to use all the resources at their disposal to further the goals of SES research, their individual efforts weren't enough to catalyze institutional change; institutional inertia stymied platform development (Méndez et al., 2012). This finding was supported by a stakeholder survey in 27 case studies (including six LTSER platforms) that operationalized the ecosystem service concept, which found that although individuals may change their views, institutional change was slower (Dick et al., 2018b).

3.8. Context-specific considerations

Despite the fact that each platform and its staff are inspired by a common theoretical framework advocated by the European LTER network, the influences of the nation-state, society, subcultures, and institutional cultures can have an overwhelming impact on whether and how knowledge is shared and actions implemented. Scholars often cite *integration* as a key measure of the effectiveness of adopting a transdisciplinary approach (Lang et al., 2012; Pohl et al., 2011; Klein, 2008). One typology of integration in transdisciplinary science specified that persistent impediments to integration can be categorized as either: a) scientific integration across disciplines, b) international integration across nations and cultures, and c) sectoral integration, across science and society (Rice, 2013). While we have endeavored to draw general conclusions about the turn toward transdisciplinarity in SES science, we caution that the particulars of implementing a program at different sites across the world will necessarily meet encouragement and barriers that are – to varying degrees – influenced by cultural phenomena of local, regional and national contexts. For example, the legacy of Communism in Romania and Francoism in Spain makes institutions more rigid, individuals less trusting, management more hierarchical, and national funding less sure than is ideal for implementing a transdisciplinary research program (Appendix V: Box 2; further examples in Appendix V: Boxes 1 and 3). These phenomena are worthy of study in their own right, and amplify the case for cross-disciplinary work, considering the improved understanding that could arise from collaborations with political scientists, economists, organizational psychologists, historians, and development studies experts.

3.9. Efficacy of assessment methodology

Overall, the key advantage of our approach was its capacity to grasp the socio-cultural, institutional, and stakeholder context, and to have in-depth discussions with a variety of stakeholders that not only gleaned responses to evaluators' direct questions, but also gave a sense of the issues most salient for interviewees, providing clues as to whether the evaluation captured the issues of greatest importance to stakeholders. The key disadvantage of the approach was the inability to delve in-depth on specific issues of interest, such as: ecological and socio-economic monitoring, data harmonization, data-sharing, and specific conservation practices. While we understood from interviews and focus groups that progress has taken place on these issues in general, we could not detail specific information about these aspects of research programs without further study. There was also the problem of attribution and additionality in this evaluation. As evaluators, we were looking for evidence of momentum or change, but, using qualitative methods, we could not attribute changes or more subtle shifts to specific variables; we could only report interviewees' *perceptions* of these links. However, since this was the first evaluation of its kind, it may be considered valuable in providing a descriptive picture from which to benchmark future evaluation work.

This participatory evaluation (Papineau and Kiely, 1996) enhanced the case platforms' offering of social science research in the short term, and, because transdisciplinary frameworks require reflexivity and self-assessment, the evaluation should be considered a part of the SES research process. The evaluation can also be considered action research (Ferrance, 2000) because it promoted aspects of transdisciplinary social-ecological science, the content that it was evaluating. Return site visits made to conduct stakeholder focus groups stimulated reflective conversations that may have been more challenging to initiate from within, and which seemed to trigger momentum for advancing SES research.

4. Implementing a novel evaluation method

This study implemented a novel evaluation framework to test the effectiveness of SES research platforms to address complex, urgent social-ecological challenges using LTSER platforms as living laboratories. In doing so, the evaluation not only tracked their goals and progress, it also asked provocative questions, prompted reflection, stimulated discussion, and facilitated meetings and new relationships, elements that are crucial to transforming work “from a new way of knowing to a new way of doing” (sensu Toomey et al., 2017). Further, it provided concrete suggestions that can be immediately implemented in the LTSER network and by others conducting SES research.

It has been suggested that the field of conservation biology has “adopted a success mindset” and that instead of only reporting successes, it would be wise to recognize, categorize, and learn from its failures (Catalano et al., 2018). In this spirit, we would like to recognize some difficulties of analyzing the RIS in the context of LTSER, and, specifically, the pitfalls of the qualitative approach used in this study. As described above, the approach did not allow for identifying correlations between research and practice. Further, the interview protocol was intentionally ambiguous so it could be used with diverse stakeholders; together with a semi-structured approach, this, in some cases, led to the ambiguity of whether the focus of the conservation was on research or implementation. While this was in line with a conceptualization of a complex RIS, it was slightly confusing for interviewees. Finally, this study emphasized an analysis of the research process. Because it did not evaluate specific research projects, but rather, research platforms, we did not focus on the applicability of SES research on biodiversity conservation policies, or on addressing their implementation failure. Because research platforms are still in their early stages of development, this study focused more heavily on knowledge production processes. Based on this analysis, several key recommendations are offered for initiators and participants in LTSER platforms in particular, but these recommendations are also relevant for place-based sustainability initiatives in general (Table 1).

5. Conclusions

The results of this evaluation reflect modest advancements toward reaching the goals of long-term, place-based, SES research. In most cases, the components for creating dynamic RIS's are present: a charismatic leader, high-quality research institutions, relationships with stakeholders, and ongoing monitoring, research, and traditional knowledge on a variety of place-based topics. However, creating links, tools, communication, and coordination among these essential parts so

Table 1
Recommendations toward integrated knowledge production for place-based sustainability.

Recommendations for platform management	Detailed suggestions
Clearly articulate and publicize the platform's mission, objectives, and expectations for research, monitoring, and other activities at the local scale	* Outline mission, objectives and implementation plan. * Include proposed activities and outputs the platform would like to produce, how they will be disseminated, and an idea of how they might be funded and who might be involved. * Define intended end-users of the knowledge products that will be created, how information will likely be utilized, and end-users time frame for research and decision-making. *Publicize activities and achievements to build momentum for partnerships and activities.
Define roles for researchers and partners	* Hire a dedicated professional to manage platform activities, whether part-time or full-time. * When asking stakeholders (including researchers) to contribute additional time and effort, find ways to reward them with additional compensation and/or credit.
Align goals of long-term observation initiatives with goals of short-term research programs at platforms	* By unifying the goals of long-term observation and short-term research programs, opportunities may arise to use resources from one to buffer shortfalls in resources for the other.
Improve knowledge exchange and accessibility of research findings	* The active use of websites and social media, distributing flyers, and hosting regular stakeholder meetings could help to make research results more accessible to a range of stakeholders. * In terms of local stakeholders, knowledge exchange activities should fit the local cultural context and should be perceived as convenient, beneficial, and, ideally, incentivized in some way, to encourage participation. * There is awareness of the need to improve database accessibility for place-based research at all sites; accessibility and plans for ongoing maintenance should be prioritized.
Incorporate social scientists, community leaders, and administrators into platform management and decision-making	* Find ways to work more closely with key individuals and institutions that may aid in integrating socio-economic monitoring and research, outreach, and cross-disciplinary and cross-sectoral exchanges into platforms. * When citizen science programs and outreach with local schools and communities exist, include them in visioning and decision-making process of LTSER. * Strive toward ongoing collaborations with leaders representing different disciplines, sectors, and stakeholder groups.
Understand and define target scales for different projects and people	* Collaborators should be clear about the scale at which a particular endeavor will be pursued, and to target stakeholders relevant to that particular issue.
Initiate structured, periodic evaluation	* Periodic evaluation to reflect upon and measure platform progress toward its goals is essential to foster continuous learning and improvement. This process could greatly benefit from participatory approaches, supported by quantitative and focus group elements, and should take place periodically into the future (perhaps every 5 years).

that they constitute effective RIS's presents many challenges. The metaphor of the bicycle (Fig. 4) – and the fact that all components must not only be present, but also fit together and be well-tuned for the bicycle to properly function — represents the phenomenon of effective transdisciplinary research as greater than the sum of its parts. While this evaluation located all the *components* of transdisciplinary, social-ecological science, these components don't yet *fit together* nor are they *well-tuned*. This is because the components were not *well-integrated* as part of an overarching strategy for designing and conducting social-ecological research. As described above, scholars have called integration a key measure of the quality of transdisciplinary research (Rice, 2013; Lang et al., 2012; Pohl et al., 2011; Klein, 2008); however, measurement of integration was not explicitly included in this evaluation. We would recommend including explicit measures of integration in future evaluations.

In this study, actors conveyed their understandings of how the RIS is situated within – and heavily influenced by – local history, culture, institutional paradigms, and power dynamics. Critics of transdisciplinarity have cautioned that the co-production of knowledge can reproduce society's existing power differentials; the ideal, however, is to strive for reciprocal, trusting relationships between different groups (Toomey et al., 2015). Toomey et al. (2015) recommend that funding

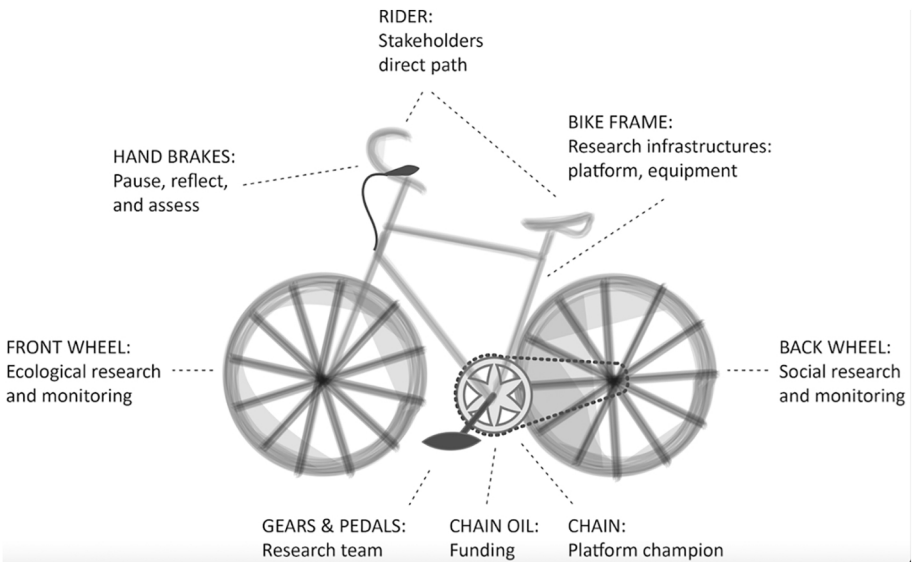

Fig. 4. A creative representation of integrated SES research. The bicycle metaphor implies that all components are essential to the sound functioning of the whole and ability to move forward. The front wheel is depicted as ecological research to reflect the historic path taken in developing social-ecological research programs, which generally began with ecological research. Credit: Ronit Cohen-Seffer, Yael Teff-Seker.

calls more clearly define exemplary research, build reflexive processes into research, and create mechanisms to ensure that large-scale projects do not diminish smaller ones. This research found that funding requirements were often found to be a critical catalyst in adopting methodological components of transdisciplinarity (e.g. stakeholder integration). It also uncovered valuable, tacit knowledge that strengthened the case for advancing reflexive social science research and evaluation to promote program improvement. The participatory design of this evaluation demonstrated to stakeholders that researchers are invested in improving the impact of their work in the real world, that they value the influence of practitioners in the knowledge production process, and that an evaluation process can facilitate effective communication among diverse stakeholders.

This evaluation marked a starting point for evaluating social-ecological research, and its effects will likely be gradual. Transdisciplinary assessments are interactive, evolving processes that occur over time (Jahn et al., 2012; Pregernig, 2006; Cash and Clark, 2001). Pregernig (2006) observed that policy impacts of environmental research are typified by delays; five to ten years can pass between the completion of an assessment and its impacts on the policy process. Such a gradual process was assumed when determining how to deliver the results of the present assessment in ways that would be useful and actionable for the case study platforms, and other, similar research infrastructures.

If a paradigm shift from disciplinary research toward integrated SES research is occurring – and, with it, a shift from conceptualizing an RIG to a RIS – then this too has been, and continues to be, a gradual process. Unlike most scientific paradigm shifts that were stimulated by scientific discoveries, this transdisciplinary turn is linked to broad shifts in science and society toward greater complexity and accelerating social and environmental change. In this context of rapid socio-environmental change and societal coping that lags behind, we believe this evaluation was well-suited to its purpose of collecting data to generalize about multiple elements of SES science at diverse sites. We hope that this framework, and the resulting observations and recommendations, help to lead the way forward for evaluating knowledge production for better conservation processes and outcomes, and that this study provides a useful account of early innovations toward relevant, actionable science for sustainability.

Acknowledgements

This paper is dedicated to the memory of Jesús Vozmediano y Gómez-Feu, environmental lawyer and champion for the conservation of Doñana National Park.

The authors are very grateful to all interviewees who took part in this study. The authors are indebted to them for sharing their knowledge, time, and wisdom with us. We also wish to thank the following individuals and teams for their contributions and support. *Methodology development*: Naomi Carmon, Karel Martens. *Site visit support:* University of Bucharest Research Center in Systems Ecology and Sustainability staff, Centre for Ecology and Hydrology - Bush Estate staff (UK), staff at Estación Biologica Doñana – Sevilla, Spain, Herbert Haubold. Support for the research carried out in Doñana National Park was provided by the Large-Scale Research Facility (ICTS) and Biodiversity Monitoring Team of Doñana Biological Reserve (EBD-CSIC). Thanks to Morgan Grove for organizing interviews at the Baltimore Ecosystem Study for interview protocol validation. *Translators:* Condruța Savu, Yaella DiPietri. *Analysis:* Efrat Eisenberg, Sarah Goldberg, Lihi Matza. *Analysis validation:* Yael Teff-Seker, Combined ecological and social-ecological laboratory members, Technion - Israel Institute of Technology. Additional thanks to Sarah Goldberg for reviewing and commenting on an earlier draft of the manuscript.

This study was partly funded by the eLTER program European Union Horizon 2020 Grant Number 654359 “European Long-Term Ecosystem and Socio- Ecological Research Infrastructure — eLTER,” including a Transnational Access grant, which supported site visits. Additional support was provided by EU Horizon 2020 Grant 641726 “EcoPotential: Improving future ecosystem benefits through earth observation,” by EU Horizon 2020 Grant 654131 “COOP+: Cooperation of Research Infrastructures to address global challenges in the environmental field,” and by Scottish National Heritage via the UK Environmental Change Network. The views expressed in this paper are those of the authors alone.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2019.108228.

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