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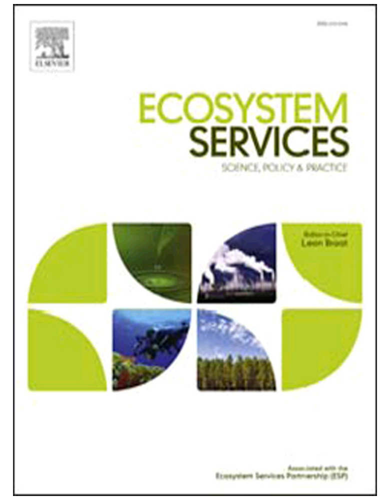

Are we seeing the whole picture in land-sea systems? Opportunities and challenges for operationalizing the ES concept

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Title: Are we seeing the whole picture in land-sea systems? Opportunities and challenges for operationalizing the ES concept.

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Abstract

The concept of Ecosystem Services (ES) highlights that human wellbeing depends on nature and is a 'whole system aware' view. Land-sea systems are examples of complex systems including interfaces that can be perceived as boundaries, overlooking connections of the whole system. We explored the occurrence of several features of scientific knowledge building and governance of these systems that can hinder the recognition of connectivity, challenging an ES approach. We analyzed online survey responses from academics representing 22 research institutions and 13 case studies, all from Latin America. Results showed that the generation of scientific knowledge is not integrally approached and there are deficiencies in researchers' communication with stakeholders across the land-sea interface. These drawbacks in scientific knowledge building could be one of the reasons why an ES approach is rarely applied on governance of land-sea systems. The cases showed segmented governance schemes and that conflict situations enhance the visibility of ecosystem relations. The establishment of long-lasting institutional instruments and the involvement of intermediaries connecting sectors are complementary paths to improve integrated governance. Using ES as a boundary concept could improve integration between sectors and ES trade-off analysis can help to introduce ecosystem relations to stakeholders related to their own interests.

Key words: scientific knowledge, environmental governance, Latin America, land-sea connectivity, social-ecological systems

1. Introduction

The concept of Ecosystem Services (ES) highlights that human wellbeing depends on nature and is a 'whole system aware' view (Costanza et al., 2017). Several conceptual frameworks have been developed linking ES and human wellbeing (Díaz et al., 2015; Kumar, 2012; Millennium Ecosystem Assessment, 2005; Watson, 2012). These frameworks are particularly focused on bridging social and ecological components of the system or science and policy. From this perspective usually complex linkages among processes and components within social-ecological systems (Box 1) are over simplified. The effect of these complex relationships has been approached by assessing synergies and trade-offs among a few ES. However, studies considering the full range of services and the characteristics of their bundling are still needed (Costanza et al., 2017) and the 'whole system' view is challenging and hardly applied (Balvanera et al., 2017; Daily and Matson, 2008). In addition, since the Millennium Ecosystem Assessment, an ES approach (Box 1) has become a central framework for scientifically assessing ecosystem change and the impacts of ecosystem change on human wellbeing. However, the application of this approach has been limited in decision-making processes and governance of social-ecological systems (Cowell and Lennon, 2014; Ramesh et al., 2015; Reyers et al., 2013; Sitas et al., 2014). According to Constanza et al (2017) limiting factors include the lack of appropriate institutional frameworks and mistrust or misunderstanding of the science. In this sense, segmented governance systems that do not align with social-ecological relationships within the system may not embrace the ES approach (Mann et al., 2015) because their institutional structures, instruments and mechanisms are not appropriate to apply a whole system view. Therefore although governance systems are in the core of ES conceptual frameworks (Díaz et al., 2015), the reciprocal relationship is not necessarily true. On the other hand, in order for science to be trusted scientific knowledge should be generated together with civil society and adequately communicated to all stakeholders (Cáceres et al., 2016; Clark and Dickson, 2003; Ramesh et al., 2015). In addition, science based on a segmented view of the system may lead to biased conclusions and misunderstanding of ES concept creating dysfunctional incentives and undesired outcomes. Overall, given that concepts from sciences influence the acceptance and application of new approaches by stakeholders (Cowell and Lennon, 2014), the absence of a whole system view in scientific knowledge building could be one of the reasons why an ES approach is rarely applied on governance of social ecological systems (Beaumont et al., 2017).

Land-sea systems are clear examples of complex systems including interfaces and many connections between the two environments within the system (Box 1). If the interface is perceived as a boundary between land and sea intrinsic connections within the system can be overlooked, challenging an ES approach. The perception of a boundary induce that different scientific disciplines and governance instruments address the two environments included in land-sea systems (Arkema et al., 2015; Carpenter et al., 2009; Norgaard, 2010; Pittman and Armitage, 2017). Scientific disciplines and stakeholders focused on terrestrial environments and those focused on marine environments often work in distinct silos, resulting in segmented science and governance (Ruttenberg and Granek, 2011). However, these two environments are connected through biogeochemical (e.g., nutrient flows) and ecological (e.g., species movements) interdependencies at different scales and are also subjected to close interaction in coastal environments mediated by social and biophysical factors (Alvarez-Romero et al., 2011; Glavovic et al., 2015; Ramesh et al., 2015). If these connections are not perceived, realized and articulated as part of integrated governance schemes, the social-ecological systems involved are vulnerable to changes (Ruttenberg and Granek, 2011). Consequently, the ability to efficiently manage interconnected environments may be compromised, potentially affecting the sustainable supply of ES and the timely detection of possible synergies and trade-offs among ES (Alonso Roldán et al., 2015; Palomo et al., 2011; Pittman and Armitage, 2017; Puente-Rodríguez et al., 2015). For example, if land use policies or environmental regulations in agricultural regions do not take into consideration the impact of run-off on coastal and marine environments downstream, it limits the ability of marine planners to conserve fish stocks through actions controlling fishing pressure, as stocks will also respond to water pollution introduced from upstream land use practices. Inversely, interactions among stakeholders can improve integration and application of diverse knowledge sources (Armitage et al., 2009), improve the capacity to detect and successfully manage undesired changes in social-ecological systems (Bodin et al., 2006; Bodin and Crona, 2009), and enhance the fit between governance and ecological systems (Guerrero et al., 2015). Therefore, it is expected that more participatory governance arrangements would promote interactions among stakeholders with a stake in different environments and improve a whole system approach to management actions. This fit between governance and land-sea linkages has been scarcely studied in Latin America (Pittman and Armitage, 2016). Thus, it is important to evaluate how governance can promote the implementation of an ES approach in the region. Likewise, a systemic approach to scientific knowledge has not been quantitatively surveyed globally or across regions. There are no quantitative studies analyzing how often terrestrial and marine researchers work collaboratively or consider variables from both environments to tackle linkages and processes across the system (but see Ruttenberg and Granek, 2011)

The research presented here focuses on scientific knowledge building and governance of land-sea systems, evaluating if there are segmentation issues that may prevent the implementation of an ES approach in Latin America. The work presented here arose from a special session of the Fifth International Congress of Ecosystem Services in the Neotropics (CISEN V, acronym for the name in Spanish "V Congreso Internacional de Servicios Ecosistémicos en los Neotrópicos") organized and coordinated for this purpose. At that session we addressed the following questions: (1) How often and to what extent does the generation of scientific knowledge in the study region include a systemic view to the land-sea social-ecological system? (2) Is scientific knowledge interdisciplinary, participatory and communicated to stakeholders? (3) Are governance schemes systemic or segmented? (4) Are there features of the social-ecological system that facilitate or promote visibility and inclusion of land-sea connectivity in governance systems?

Box 1. Terms and concepts

Ecosystem Services (concept): are the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing: that is, the benefits that people derive from functioning ecosystems (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005)

Ecosystem Services approach: concepts, practices and protocols to apply the ES concept to the management of social-ecological systems. Here we mainly consider the characteristic of being an integrative and "whole system aware" approach.

Social-ecological systems: complex adaptive systems where social and biophysical agents are interacting at multiple temporal and spatial scales (Janssen and Ostrom, 2006; Ostrom, 2009)

Governance: is the interaction among institutions, processes and traditions that determines how power is exercised and how decisions are made on issues of public and often private concern (Schliep and Stoll-Kleemann, 2010).

Environmental governance: refers to the broader processes and institutions through which societies make decisions that affect the environment (Armitage et al., 2012).

Land-sea systems: in this article refer to a single entity that comprises land and sea realms. Given that we seek to highlight relations or gaps linking both realms we mention the components of the system as terrestrial or marine (see Terrestrial environment and Marine environment).

Terrestrial environment: in this article refers to the portion of the system on land.

Marine environment: in this article refers to the portion of the system in the sea.

Boundary concepts: allow thinking and conceptual communication about the multidimensionality and complexity of issues (Mollinga, 2010).

2. Methods

To address the research questions, we distributed an on-line survey to academics from diverse research institutes and universities (questions one and two) and applied a case study comparison (questions three and four) comprising eight Latin American countries. The choice of institutions to distribute the online survey and the selection of cases represent the connections and expertise of the researchers attending the CISEN V special session and authoring the present article. Therefore, the collated information, although representative of different countries and social realities, did not attempt to capture all of the variation presented in Latin America. Nonetheless, our involvement in case studies and our work in selected institutions allowed access to non-published data and more in-depth interpretation of collected information and results, beyond the original aims of research in the case studies.

2.1 Survey

Prior to the special session we agreed on the questionnaire and then we distributed the on-line survey to individuals at 22 institutions (see the list of institutions in supplementary material 1). The institutions were selected by the relationship with case studies due to our affiliation or the affiliation of other researchers working in the social-ecological systems of case studies. We included universities, research institutes and NGOs, some of them specialized and others covering a full range of disciplines and topics. In each case we attempted to distribute the survey in the whole institution in order to reach departments or working groups undertaking more/less integrative work. We initially asked the respondents to select the environment where they mainly worked: marine or terrestrial. Then the survey questions referred to the environment they did not select as “the other environment”: terrestrial if they mainly work in marine environment and marine if they mainly work in terrestrial environment. In this way we highlight the focus on and connections among components of the land-sea system. Those researchers working in both environments or in an integrative way could show it in following responses (see the complete list of questions in supplementary material 1). In addition, we characterized the population of respondents by asking about their main research topic and the amount of time they worked in this research area. To explore if researchers are considering marine and terrestrial components of the systems comprehensively through networking, we asked about collaboration with colleagues working in the other environment and the results of these collaborations. To identify the factors of the land-sea linkages that are being considered, we asked if the researchers included variables from the other environment in their studies, and which ones. However, researches may consider the system as a whole, even though it is not reflected in collaborative work or the inclusion of specific variables. Thus, we asked if they identified factors of one environment that influence the other and the challenges of including them in their research, even if they acknowledge these factors. To address research question two, we asked respondents about collaboration with colleagues from other disciplines, the development of or participation in activities with other sectors, as well as the communication of results to different sectors of society and their application in management actions. Finally, to explore if researchers identify the segmentation in results communication as a problem, we asked about the possible threats and conflicts that may arise if study results focused on one environment do not reach stakeholders from the other environment. During the session we revised the general outcomes and agreed on data analyses.

We performed descriptive statistics to explore answers to the topics covered by the interview. To test if the perception of researchers of the system as a whole is reflected in their work, we compared the frequency of researchers including variables from the other environment in scientific studies to the frequency with which they identified variables or factors connecting land and sea by performing χ^2 tests on contingency tables. We also performed this test in order to detect and explain patterns in the extent to which a systemic view is applied by researchers according to the environment in which they are focused, the amount of time over which they were developing the research and the relation of the research topic with land-sea interactions and management. To do this the research topics were classified into three categories: "related" to land-sea interactions, "unrelated" and relative to "management". We performed all analyses using R (R Core Team, 2016).

2.2 Case study comparison

To address the questions related to environmental governance (research questions three and four), we explored 13 case studies contributed to the CISEN V special session from our previous experience (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Ruttenberg and Granek, 2011). We included inland, coastal, island and marine systems, representing different ecosystems (semi-arid shrub land, grasslands, forest, mangroves, wetlands, coral, seagrass, coastal marine and marine continental shelf) and different degrees of formal protection (some declared as protected areas under diverse institutional arrangements and some without formal declaration; cases are described in supplementary material 2). To characterize the cases, we used information available from our previous research on the case studies. Therefore different sources of information and data gathering techniques were involved (Eisenhardt, 1989). In order to condense all the relevant information to compare case studies, prior to the CISEN V we developed an analytical framework selecting the relevant topics/features to answer research questions three and four. To develop this analytical framework we interacted via e-mail and an on-line editable document, where we proposed relevant topics/features based on our expert opinion. Then, to facilitate the comparison of case studies and identification of patterns, we built a matrix with summarized information of case studies for each topic/feature of the analytical framework (supplementary material 3) following the inductive process proposed by Eisenhardt (1989). The discussion and comparison of the case studies during the CISEN V special session enabled us to identify challenges and threats to the application of an integrative approach to environmental governance of the land-sea social-ecological system and to make recommendations on how to improve it. Following we detail topics/features that we compared to answer each research question.

We analyzed the degree of governance segmentation in the cases (research question three) by examining and quantifying the interactions between stakeholders. To do so, known stakeholders in each case were classified as land-focused, sea-focused or mixed. To characterize and quantify interactions among stakeholders, we built social networks and calculated the E-I index using R (R Core Team, 2016). The E–I index measures the extent to which macro-structures, like the blocking by environment, "cluster" the interaction patterns of nodes that fall within them, and compares the numbers of ties within groups and between groups (Hanneman and Riddle, 2005). The index ranges from -1 (all ties are internal to the group) to 1 (all ties are external to the group). We expected more ties among stakeholders focused on the same environment and index values from -1 to 0 if governance schemes were segmented. In addition, we searched for patterns in features of examined systems that may facilitate or obstruct the governance of the system as a whole, like the degree of protection, the level of stakeholders' participation in institutional bodies for decision making (according Berkes' Ladder of Participation; Berkes, 1994), instruments driving stakeholder interactions related to different environments (terrestrial and marine), dominant environment and geographical context (inland, coastal, island or marine).

We looked for features of the social-ecological system that facilitated or promoted visibility and inclusion of land-sea connectivity in governance (research question four) by comparing case studies for acknowledgement of ecosystem relations by the stakeholders and whether these relationships were addressed by features of the governance schemes. We also searched for patterns in the visibility of ecosystem relations arising from conflict between stakeholders with a stake in different environments.

3. Results

3.1 Survey

A total of 313 respondents answered the survey. This represents 15.4% of the population contacted for the survey (see a quantitative description of the population in supplementary material 1).

Results showed that considering marine and terrestrial components of the systems comprehensively through networking or the inclusion of variables from the other environment was not standard practice among researchers. Approximately half of the respondents (49%) collaborated with colleagues focused on the other environment (Fig. 1), with a scientific article as the most frequent result of that interaction (Fig. 2 C). Similarly, 47% of respondents have included variables from the other environment in their study (Fig. 1). The combined responses of respondents for these two questions of the survey account for 67% of respondents that have collaborated and/or included variables from the other environment (added values of respondents that have "collaborated and included variables", "only collaborated", and "only included variables"). Among the rest, 14% have only identified variables but did not collaborate and/or include variables in their studies, while 19% have neither collaborated nor included or identified variables. The difference between the proportion of researchers who included variables and those who identified variables (χ^2= 26.563, df = 1, p-value = 2.55 x 10^{-7}) could be related to difficulties that respondents experienced in recording the identified variables in their studies (Fig. 2 D). There is also a difference between the variables identified and those most commonly included. The variables most commonly included from the other environment were social, followed by meteorological and biological ones (Fig. 2 A). The most frequently identified variable or factor from one environment affecting the other was transport of sediments and nutrients (Fig. 2 B).

Several patterns emerged relating to the extent to which researchers consider the system as a whole and features of the surveyed population. Researchers working in terrestrial environments tend to collaborate less with colleagues from the other environment (χ^2= 10.964, df= 3, p= 0.012) compared to researchers working in marine environments. However, no significant difference was found in the inclusion or acknowledgment of variables from the other environment between researchers working in terrestrial environments and researchers working in marine environments (χ^2= 6.67, df = 3, p= 0.083, and χ^2= 7.79, df = 3, p= 0.05 respectively). In addition, researchers working on the topic for one to five years collaborate with colleagues from the other environment less often than those who have been researching for a longer time (χ^2= 15.995, df = 4, p= 0.003). Researchers working on the topic for more than 10 years tend to include variables from the other environment (χ^2= 15.995, df = 4, p = 0.003) and to identify those variables in higher proportion than researchers developing the topic for less time (χ^2= 10.743, df = 4, p = 0.029). With regards to relating the research topic with land-sea connectivity and management, researchers with unrelated topics collaborate less with colleagues from the other environment and researchers involved in management topics collaborate more (χ^2= 6.396, df = 2, p= 0.041). No significant differences were found in the inclusion of variables from a different environment among researchers working on the three classes of topics (χ^2= 2.065, df = 2, p= 0.356). However, researchers with unrelated topics acknowledge variables from one environment affecting the other less frequently than researchers working on topics related to land-sea interaction or management (χ^2= 9.136, df = 2, p= 0.01).

Results showed that scientific knowledge building is interdisciplinary and participatory. Most respondents collaborated with colleagues from other disciplines (81%) and many (62%) developed or were involved in participatory activities. The stakeholders involved in these participatory activities and receiving the research results represented government, NGOs and resource users (including community, private enterprises, individual or organized producers and independent professional users of knowledge; Fig. 3 A and C). However, results exposed deficiencies in communication of scientific results. A high proportion of the respondents were not in contact with stakeholders so as to transfer the results of their research (36.74%) and only 22.36 % of the respondents were in contact with stakeholders from both environments (Fig. 3 B). Many of the researchers that transfered their results to stakeholders did not know if they were applied to management actions or whether these actions were effective or not (Table 1).

Researchers did not identify the segmentation in the communication of results as a problem. A high proportion of respondents (43%) did not identify threats or conflicts if the information about one environment did not reach stakeholders involved in the management of the other. When consequences were identified by respondents, the most common were "Ecosystem degradation" (12%), "Poor resource management" (10%), "Impacts due to discharge or transport of substances" (8%), "Ineffective management actions" (7%) and "Conflicts in land/sea-use management" (7%; Fig. 3 D). Among the less frequently identified threats were: loss of ecosystem services, loss of opportunities, loss of social capital, economic impacts, cultural impacts, asymmetric appropriation of costs and benefits, impacts due to buildings (coastal cities and dams), erosion and dunes mismanagement and fractured management regardless of matter and energy flows (grouped in “Other”, Fig. 3 D).

3.2 Case study comparison

Examination of different features across the case studies showed that governance systems are segmented since all values of E-I index are negative (Fig. 4 A-B). In addition, case studies focused on terrestrial environment showed less interaction among stakeholders from other environments (land-sea) than case studies focused on marine environment, while coastal and island systems were between those extremes (Fig. 4 A). Governance schemes showing a higher degree of interaction of stakeholders from different environments (land-sea) are close to extremes in Stakeholders' participation in institutional bodies for decision making according to Berkes' Ladder of Participation (Berkes, 1994) "government centralized management" and "community self-governance and self-management" (Fig. 4 B). The main features and number of cases as referred hereafter are presented in Table 2, with complete information in supplementary material 3. Interaction among stakeholders from different environments and integrating management approaches are generally insufficient for implementing an ES approach to governance due to the presence of segmented institutional arrangements, legislation and mandates of governmental agencies. Nonetheless, in several cases long-lasting institutional instruments have been established. Such instruments were wide-reaching management plans encompassing several protected areas or other planning and conservation tools (e.g. cases 1, 4, 7, 12), wide-ranging ordinance plans (encompassing sea and land; e.g. cases 6 and 7), umbrella legislation that articulates and integrates minor sectorial pieces of legislation (e.g. cases 4, 7), and relatively stable institutional bodies for decision making like committees or boards with diverse sectors represented (e.g. cases 3, 4, 5, 8, 11, 12). In other cases, collaboration and interaction has occurred more circumstantially, such as collaborations held between some sectors to accomplish specific activities (informal interactions, workshops, Memorandums of Understanding signed between some sectors to collaborate in specific short to medium term projects or activities; e.g. cases 2, 3, 6, 10).

Some interesting insights emerged when comparing cases with regards to governance integration across environments through observing the presence of institutional arrangements for integration, the level of stakeholder participation for decision making, the degree of interaction among actors from different environments, and the main obstacles for integration. In a set of cases (4 of 13) NGOs played a critical role in connecting, horizontally and vertically, sectors from diverse environments, still in the presence of institutional arrangements like protected areas that encompass sea and land sectors, but where a highly centralized governance predominates (several Mexican cases: 8, 10, 11 and case 3 in Costa Rica). NGOs have prompted the implementation of local initiatives and decision-making arenas where joint action is encouraged, while centralized governments retain management authority. A possible weakness might be the institutional fragility of these bodies, at least at their initial stages, due to the lack of robust legal backing compared to other institutional arrangements created in the context of existing legislation. Another set of cases (5 of 13) showed moderately to highly elaborate institutional arrangements (management tools, legislation, decision making arenas) for integration across environments compared to previous cases, but they also had in common limitations in implementation, with deficiencies in coordination and articulation among agencies and sectors. Integration was challenging to achieve in practice, even when comprehensive tools and legislation were in place (cases 1, 4, 6, 7, 12). Two of the cases highlighted important geographic limitations for integration (case 2 and 13). These cases focused on one environment and emphasized the lack of institutional arrangements for integration across environments. They faced difficulties in integrating research and governance of environments that were connected through the provision of ES but distantly located from one another. Institutional rigidity was also mentioned in some cases as an obstacle to integration (case 7, 9), as well as limited resources (time, personnel, and monetary resources; cases 1, 3, 8). Stakeholders' participation in institutional bodies for decision making ranged from "informing" or "consultation" in several cases (Berkes, 1994) to “joint action” or “advisory roles” in a few cases. Formal participatory bodies enhanced interactions between diverse stakeholders, increasing the exchange of knowledge/information, perspectives and expectations, despite governmental authorities retaining management authority.

Overall, cases examination showed that ecosystem relations are not sufficiently accounted for in management initiatives nor recognized by stakeholders. In some cases, ecosystem relations were not acknowledged at all (e.g. 1, 2, 8) and in others they were partially recognized but not by key stakeholders (e.g. 6, 9, 10, 11). Case studies suggested that ecosystem relations are generally perceived by the public when the effects of human interventions are quite visible, affecting the daily lives of people in critical ways (e.g. cases 3, 4, 5, 7, 12, 13). In most cases ecosystem relations were not accounted for in management (7 of 13 cases), even when they were acknowledged by stakeholders (e.g. cases 3 and 13). In some cases, they were partially considered when analyzing the environmental impact of new activities (e.g. 6), or because some stakeholders had recently promoted articulation and integration of management activities, despite difficulties (e.g. cases 7, 9, 12). We found several factors that facilitate visibility for the consideration of ecosystem relations in the social ecological system governance. For example when a large proportion of communities relying on the provision of ES such as drinking water the ecosystem relations involved in the supply of the ES became relevant and acknowledge by stakeholders. Legislation on environmental governance can make explicit ecosystem relations. Short distances between source and places receiving the impact of activities help stakeholders acknowledge cause-consequence procecesses relying in ecosystem relations. Geographical features (mountainous, steep slopes, heavy rains) and intermediary stakeholders can generate conditions that make ecosystem relations more evident. On the other hand, cases also illustrated factors that obscure the visibility of ecosystem relations. For example if impacts of an activity are extensive in space and time it is more difficult to stakeholders to relate it with effects through ecosystem relations. Also, with underwater flows instead of surface water flows, water pollution is essentially invisible. In inland cases we saw that richness of natural resources and regional supply autonomy, low education level in the community, dominance of local problems, and segmented administrative schemes are factors that prevent stakeholders to draw attention to ecosystem relations connecting their community at regional scale. Several patterns and key elements emerge when considering the acknowledgement of land-sea ecosystem relations by stakeholders across case studies. We observed that when the systems were not coastal, terrestrial social-ecological systems did not include the marine environment or its effects on it (e.g. cases 5, 7, 13). Also, the impacts of terrestrial activities on ecosystem functions in the marine environment predominated (downstream direction). Consequently, it was more likely that the ecosystem relations were noticed and included in management actions in the coastal and marine environment, focusing on the effects rather than the causes of impacts. Moreover, distance and scale make the perception of the connectivity and effects between environments difficult (e. g. cases 2, 7, 13). In general, marine impacts on terrestrial environments are related to climatic and atmospheric processes operating at large scale, making them more difficult to perceive. On the other hand, conflicts among stakeholders contributed to making ecosystem relations visible (Fig. 4 C). However, many cases failed to connect any negative impacts on ES with loss of productivity and other economic benefits, thus overlooking the social connectivity of the whole system. Yet, we also observed that shortage conditions as those related with drought and catastrophic events tend to make system connectivity visible.

4. Discussion

The research presented here has analyzed the occurrence of several features of scientific knowledge building and governance in land-sea social ecological systems that can promote or hinder the recognition of system connectivity, as a key aspect for the implementation of an ES approach. To the best of our knowledge, it is the first study of this kind for Latin America. The results of our analysis are not a complete description of the situation in the region, but they are useful in drawing attention to aspects which contribute to understanding why an ES approach has had limited success in informing and supporting decision making processes (Cáceres et al., 2016; Cowell and Lennon, 2014; Ramesh et al., 2015).

While scientific knowledge has traditionally been disciplinary and focused on one environment, marine or terrestrial, the results of our research show that 49% of researchers have been working collaboratively across environments to generate scientific knowledge. Considering that the researchers that declared they include factors or collaborate with colleagues from the other environment may have done it only once in their careers, the application of a systemic view in the scientific process of building knowledge could have been overestimated. In addition, 53% of researchers fail to include factors from both the terrestrial and marine components of the system in their specific research approaches. We can assume that researchers who did not include variables from the other environment did not need them to make conclusions addressing their research questions, topics and systems, given that they acknowledged the importance of such variables. These results suggest that research questions about land-sea connectivity are not being addressed. Similarly, marine and terrestrial ecologist from the USA fail to consider connections among linked marine and terrestrial environments (Ruttenberg and Granek, 2011). Given that concepts from sciences influence the acceptance and application of new approaches by stakeholders (Cowell and Lennon, 2014), a lack of research incorporating land-sea connectivity could be one of the reasons why an ES approach is rarely applied on governance of land-sea systems in particular and of social ecological systems in general (Beaumont et al., 2017). The lack of a whole system view, as was detected at least in a part of the scientific community by our survey, undermines the understanding of nature-human wellbeing relationship, complicates the synthesis of available information in an integrative way and reduces the likelihood of detecting and managing undesired outcomes and impacts (Glavovic et al., 2015). Even though several conceptual frameworks for ES have stressed the importance of an integral approach of social and ecological components (Díaz et al., 2015; Kumar, 2012; Millennium Ecosystem Assessment, 2005; Watson, 2012), more attention is needed regarding internal relations within ecosystems and institutions/governance systems. In this context, taking the ES concept to the practice research needs to focus on trade-offs and synergies, integrative modeling and bundling of ES (Beaumont et al., 2017; Costanza et al., 2017). These research areas are challenging because of the great amount of information required, especially if new research cannot rely on previous knowledge because represent a partial view of ecology. In this context, local and disciplinary approaches are valid, necessary and a way to achieve feasibility, but for them to be integrated systemically they must be designed taking into account the links of the studied portion with the whole system.

Results also suggest that not considering marine and terrestrial components of the systems comprehensively could be related to difficulties that respondents experienced in recording influencing variables. The obstacles we find when integrating variables from both environments, such as lack of time and access to information, could be overcome promoting research agendas and programs focused on system connectivity. In addition, logistics problems (i.e. difficulties in coordinating an oceanographic cruise and an in-land sampling, or limitations in the availability of measurement/sampling instruments specific to marine/terrestrial variables), which are the most frequently mentioned, could be addressed by fostering networks and coordinated collaborative organizations. Research agendas focused on system connectivity and coordinated collaborative organizations implemented complementarily can facilitate that disciplinary and local scale research could be integrated systemically, but it is necessary a whole system view in the conception of research and collaboration to achieve an integrative approach. Fostering networks is already happening worldwide, as evidenced by the increasing number of global associations and organizations that are supporting networks of regional research and collaboration for the purposes of building comprehensive regional and global governance (Glaser and Glaeser, 2014). However, some regional and global organizations propose a segmented approach, in line with our findings: the indicator framework for the European Biodiversity Strategy to 2020 (Maes et al., 2016) proposes an ES assessment divided into ecosystem types and the SDGs of the United Nations (https://sustainabledevelopment.un.org/sdgs) separate life below water from life on land goals. Also science-policy efforts focused on nature-human wellbeing and sustainable development (i.e. IPBES (Díaz et al., 2015), PECS (Balvanera et al., 2017), LOICZ (Ramesh et al., 2015), SDGs, Aichi targets https://www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-ES.pdf) should embrace an integrative approach, where the important thing is not so much to know the different components of the system but to understand the interrelationships that are established between them well (Clark and Dickson, 2003; Kates, 2011; Ostrom, 2009), and not only relating social to natural components but the actors and factors within social and natural components as well.

Our results show that, in general, the process of building scientific knowledge is interdisciplinary and participatory, interacting with stakeholders from all sectors. These characteristics have the potential to transfer scientific knowledge to management actions (Bennett et al., 2015; Cáceres et al., 2016). However, our survey detected deficiencies in transferring results to society for improved management and governance. Many researchers communicate their results only to stakeholders related to their focus environment, and do not recognize problems or impacts if information from one environment does not reach stakeholders from the other environment. Incomplete communication enhances the disconnection between environments, making it difficult to achieve an informed governance of the system as a whole. Also, management actions based on segmented knowledge can lead to undesired consequences, generating mistrust in sciences, one of the mentioned limiting factors of taking the ES concept to practice (Costanza et al., 2017). Besides, the results suggest that the mechanisms for monitoring how stakeholders use information generated by researchers are still poorly developed. In most cases, the researchers do not know if their recommendations were applied to management actions or if these were successful. Facing urgent problems in conservation and sustainable development today requires improved communication between decision-makers and scientists to promote evidence-based decision-making while improving system knowledge by means of adaptive management (Costanza et al., 2017; Cvitanovic et al., 2015a; Glavovic et al., 2015). Therefore the gaps detected by our survey not only affect the implementation of ES approach but the communication between science and policy in general as well, as stated in numerous publications (see i.e. Balvanera et al., 2017; Cash et al., 2003; Hauck et al., 2013; Maes et al., 2013; Reyers et al., 2015; Wong et al., 2015). Some recognized factors undermining this communication are lack of funding or time for communication, that researchers feel discouraged them from even pursuing knowledge exchange and prefer peer-reviewed papers over stakeholder engagement and outreach activity, and that information in these sources takes long time to be published and is usually not available to decision-makers (Clark et al., 2016; Cvitanovic et al., 2015a). Four approaches are suggested in order to improve knowledge exchange: knowledge co-production (stakeholders are involved from the onset of research-policy development), embedding (of scientists in organizations dominated by decision-makers), working with knowledge brokers (intermediaries from the science side), and boundary organization (a separate entity and perhaps less biased and capable of representing both sides; Cash et al., 2003; Cvitanovic et al., 2015b). Some responses to our survey suggest that performance assessment indices within research and founding organizations are coercing researchers to the preferences earlier mentioned. The same indices will prevent their involvement in embedding or knowledge brokers approaches. Instead knowledge co-production legitimizes researchers as active change agents (Reyers et al., 2015; Swilling, 2014) to improve knowledge exchange while responding to incentives from performance assessment indices. Even though our survey didn't gather data on knowledge co-production, detected failures in researchers-stakeholder communication can be interpreted as an absence of co-production processes. Knowledge co-production and boundary organizations should be encouraged and implemented to improve science-policy communication, although these approaches will present limitations mainstreaming an ES approach as we propose here, if organizations do not promote a whole system view (as discussed previously) or unless all actors are included (as is next discussed regarding governance schemes).

In many of our case studies the governance schemes were described as segmented, with low levels of interaction between sea-focused and land-focused stakeholders. This result is not peculiar to Latin America, as governance schemes in land-sea interface tend to be segmented, weak and complex with deficiencies in effective governance (Glaser and Glaeser, 2014; Glavovic et al., 2015; Ruttenberg and Granek, 2011). According to our results, the obstacles to integration are rigid institutional arrangements, legislation and mandates of governmental agencies, which generally start and end at the shorelines, and limited resources (time, personnel, and monetary resources). These findings are similar to those reported for USA land-sea systems management (Ruttenberg and Granek, 2011). As we stated in the introduction, governance schemes and institutions are in the core of ES conceptual frameworks and are key to connecting nature and human wellbeing. Yet they usually fail to capture and take into account the effect of relationships among actors (Berbés-Blázquez et al., 2016). Segmentation in governance has various consequences that an ES approach intents to avoid: (1) land-use management that ignores environmental impacts on coastal ecosystems and communities, because not all relevant actors are included (Alvarez-Romero et al., 2011; Glavovic et al., 2015); (2) failure to anticipate and manage impacts of change as a result of restricted flow of information among stakeholders participating in the management of both environments (Bodin et al., 2006; Bodin and Crona, 2009); (3) conflicts related to responsibilities in environmental costs, traditionally excluded, not clearly identified or assumed for vulnerable communities, as illustrated by our cases where water quality is impacted. In such a context, it is important to discuss how meaningful partnerships across sectors can be promoted in order to integrate governance schemes toward the implementation of an ES approach. The examined case studies suggest two possible paths, not mutually exclusive but complementary: (1) establishment of long-lasting institutional instruments (i.e. protocols and decision workflows determined by law), and (2) intervention of intermediaries connecting, horizontally and vertically, sectors from diverse environments. Management tools, legislation and decision-making bodies would create an institutional framework for integration in order to make sector interaction explicit, long-lasting and meaningful in terms of governance (Reyers et al., 2013). However, such implementations are usually hampered by deficiencies in resources, coordination and articulation among agencies and sectors. NGOs can play an important role prompting the implementation of such institutional instruments and facilitating communication and joint action among stakeholders from different sectors. The key role of intermediaries in implementing new approaches and practices in environmental policy has been reported in several cases (Cowell and Lennon, 2014). However, these interventions are not enough without robust legal backing and appropriated institutional arrangements.

We did not find characteristics of the social-ecological system that facilitate or promote visibility and include ecosystem relations in governance. On the contrary, our cases show that social-ecological connections between environments are less likely to be noticed and addressed when processes operate at large spatial distances or at regional or global scales. Overlooking these connections leads to environmental justice problems (Correa and Díaz Cano, 2012) that involve uneven distribution of environmental costs among stakeholders across misperceived boundaries (Andrade et al., 2011). ES conceptual frameworks usually refer to scales explicitly but making these concepts operational is challenging. The difficulty resides in presenting management problems associated with abstract processes at large scales when interests are usually local, given that concepts or approaches in the wrong scale or without the appropriate spatial resolution could be resisted by some stakeholders (Cowell and Lennon, 2014). The conceptual framework proposed by Constanza et al (2017) reflects geographically-distant demands originating in globalization and international trade as cross boundary flows. This conceptualization may solve the perception of interfaces as system boundaries but if social-ecological connections are not perceived, cross boundary flows will be overlooked as well. Furthermore and beyond problems of scale, our results show that the acknowledgement of ecosystem relations by stakeholders is partial and not sufficiently accounted for in management initiatives. The visibility of ecosystem relations is enhanced by conflicts and catastrophic events. However, conflicts are based on different uses of the system, ignoring the ecosystem factors or functions upon which those human uses rely. In many cases the impacts on production or economic benefits are not perceived by the community, ignoring the social connectivity of the whole system. Therefore, an ES approach has not yet been applied. Moreover, it will be difficult to mainstream ES into policies if ecosystem relationships and the positive or negative impacts of policies on ecosystems and their services are not considered during both the policy design and the policy implementation phase (Maes et al., 2013).

We have discussed, up to now, segmentation as a challenge to taking the ES concept to practice but it can be seen as an opportunity. The ES as boundary concept could be used to improve integration between sectors approached by our research questions: (1) among different disciplines as it provides a common language; (2) among policy makers and different scientific disciplines together via collaboration on a common task (sustainability); (3) among stakeholders as it highlights a common interest (Abson et al., 2014; Mollinga, 2010; Steger et al., 2018). In addition, and regarding our research question number four, an ES approach can help to introduce ecosystem relations to stakeholders related to their own interests by modeling change scenarios that show possible trade-offs before conflicts arise. This approach is useful to making the relationships among ecosystem structure, function and services explicit (De Groot et al., 2002), which is important for achieving integrated management, even when some ecological relations are already intuitive for stakeholders (Arkema et al., 2015).

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Figure captions

Fig. 1. Extent to which a systemic view is applied by researchers according to the environment in which they are focused (Panels A-C; T = terrestrial inland, TC = terrestrial coastal, M = Marine offshore and MC = Marine coastal), the time they were developing the research (D-F) and the relation of the research topic with land-sea interactions and management (G-I). Panels A, D and G show the collaboration with colleagues working in the other environment (terrestrial or marine as appropriate); B, E and H show the inclusion of variables from the other environment in the research; C, F and I show the identification of variables from one environment that affect the other. Scale indicates proportion.

Fig. 2. Variables from the other environment (terrestrial or marine as appropriate) included in research by respondents (A); variables from one environment affecting the other identified by respondents (B); outcome of interactions with colleagues working in the other environment (C); research difficulties in including the identified variables in their studies (D). Scale indicates frequency.

Fig 3. Socialization of science. Sectors involved in participative activities with respondents (A); transfer of research results to stakeholders from different environments (B); sectors to which respondents transfer their results (C); threats or conflicts identified by respondents if the information related to one environment does not reach stakeholders involved in the management of the other environment (D). Scale indicates frequency.

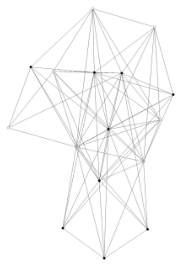
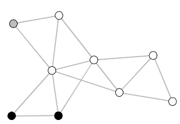
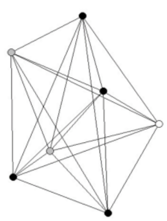
Fig 4. Upper panels show the relationship between the degree of interaction of stakeholder from different environments (land-sea) quantified by E-I index and: (A) type of environment (i.e. Inland= In, Coastal = Cs, Island =Is and Marine = Ma) and (B) model of governance (i.e. Informing= If, Consultation= Cn, Cooperation= Co, Communication= Cm, Information exchange= IE, Advisory Role= AR, Joint Action= JA and Partnership = Pr). Lower panels show the relationships between the stakeholders' acknowledgement of ecological land-sea interaction and: (C) the presence of conflicts between stakeholders from different environments (land-sea) and (D) type of environment. Dot size is proportional to the number of cases.

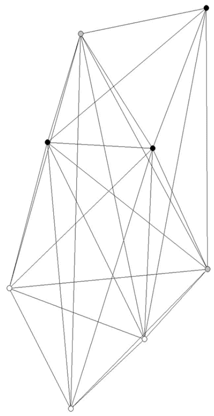
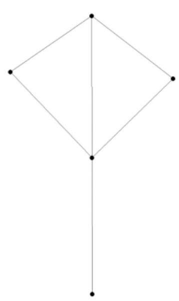
Tables

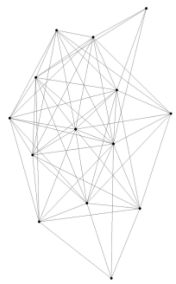
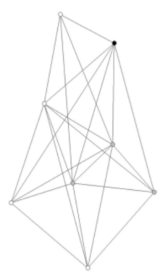
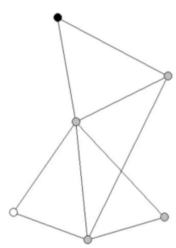
Table 1. Transfer of scientific knowledge. The table displays the percentage of respondents that were in contact with stakeholders to transfer the results of their research, percentage of respondents whose results were applied to management actions (of the researchers that transfer their results) and the perception of respondents about effectiveness of management actions based on their results.

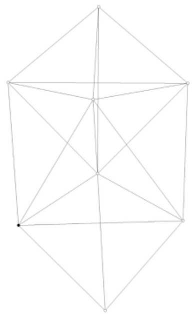
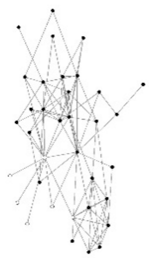
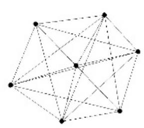
	Yes	No	Don't know
Transference of results (N= 313)	36.74%	63.26%	-
Application to management (N=198)	44.95%	14.14%	40.91%
Effective action management (N=98)	64.04%	7.87%	28.09%

Table 2. Case study comparison. Black nodes in networks represent land-focused stakeholders, white nodes represent sea-focused stakeholders and grey nodes represent mixed.

	Location/ Environment	**Interactions among stakeholders**	**Integrative institutional arrangements present?**	**Obstacles for integrated management**	**Stakeholder acknowledgment of ecosystem relations**	**Conflict due to management of one environment affecting the other**
1	Península Valdés, Patagonia, Argentina. Coastal.		A PA that embraces both environments. An integrative Management Plan in place, but scarcely implemented.	Management Plan scarcely implemented. Bodies for decision making are sectoral and there is weak articulation and coordination among agencies in charge.	Partially: especially the users and other local residents are aware of connections when they are able to perceive impacts. Other impacts may not be so visible.	Beach access and use; tourism affects fish habitat
2	Fishing ground near Puerto Rawson, Chubut, Argentina. Oceanic.		Without integrative instruments of terrestrial and marine environments.	Government administration is segmented.	There is no acknowledgment.	Waste from fishing activities and industries devoted to logistics and exportation of fishery products contaminate Chubut river and the adjacent Rawson city.
3	Osa Peninsula, Puntarenas Province, Costa Rica. Coastal.		A PA (conservation area) that embraces both environments. The case study ("blue carbon initiative") concentrates on mangrove wetlands located within the PA but under federal jurisdiction.	Lack of resources (money, people, time) by PA administration and NGO.	Workshop participants acknowledged that ecosystem services are affected.	The problem is that the mangroves are protected but the coastal zone is a public area. Everyone should care about it, but nobody does.

4	Galapagos Biosphere Reserve, Ecuador. Island.		A Management Plan integrates management of PAs present and establishes that the region ought to be managed as a marine and terrestrial social-ecological system. Presence of elaborated institutional instruments aimed at integration.	Difficulties to implement/comply with some agreements. Weak articulation and coordination with other entities (e.g. those that manage urban zones outside the PA). Information is dispersed, underutilized and inarticulated.	The National Park Administration has proposed Galapagos as a social-ecological system. Indeed, it is important to build awareness of the comprehensive links between the ecological and social aspects that are related to the management and governance of the protected area, the marine reserve and the biosphere reserve.	There are some conflicts of use between the fishing and tourism/diving sector. Moreover, in the terrestrial areas, there are some conflicts between the tourism sector and the environmental sector (national park and NGOs). Furthermore, there are some problems between the cruise-ship tourism (marine) and the community-based tourism (terrestrial).
5	Quebrada de los Cuervos Protected Area, Treinta y Tres Municipality, Uruguay. Inland.		A PA that covers the terrestrial environment with fluvial systems as key conservation target. The Management Plan links provision and use of key ecosystem services. An Advisory Commission of the PA serves as a participatory board.	Policies fragmented by institution. Lack of enforcement of anthropic activities generates conflicts. Few bodies for participation of community actors. Power imbalances make consensus difficult.		Land-use changes
6	Ejido San Lucas, Municipality of Mulege, Baja California Sur State, Mexico. Coastal.	No interaction	The main integrative instrument of land and sea environments is the Marine Ecological Ordinance Plan of the Gulf of California.	Institutional incoordination.	By a small sector of fishermen and owners it is recognized. The other actors know the importance of these services.	Environmental regulation prevents certain uses such as infrastructure and aquaculture in an area of 100 meters around the mangroves. This fact, while protecting the mangroves, is perceived by the owners of the land as a measure that impedes their well-being.

7	Chico river basin, Colombia. Inland.		Several planning instruments present (e.g. Biosphere Reserve, watershed management plans, mangrove zoning plans) are integrated in an Ordinance and Integrated Management Plan of Coastal Environmental Units. A watershed committee was created to attend to the articulated needs of the territory.	According to regulations, investment cannot be generated outside jurisdiction, which limits the integrated management of continental and marine ecosystems. Problems of coordination and territorial articulation.	Experts, local leaders and local government acknowledge the ecosystem relations between water problems, but the relationships between soil and ecosystem services are not easily identified and recognized.	Regulations for land conservation have created territorial conflicts.
8	Quintana Roo, Mexico. Coastal.		There are institutional mechanisms in place to encourage cross-sectoral partnerships and collaborations. A PA that protects both the land and the coastal zone.	Lack of resources (money, people, time). Sometimes the interests of some sectors are above any institutional instrument (corruption).	Most stakeholders recognize that water quality is a big problem and that poor water sanitation of the urban and hotel population is causing it.	Conflict is between development and environmental quality.
9	Fernando de Noronha, Brazil NE. Island.		Two PAs that embrace terrestrial and marine environments, holding distinct categories of protection. Lacks institutional arrangement that articulates management of both areas.	The system is limited by the category of protection. Centralized government limits actions.	Managers, fishers, businessmen and a part of the community are aware of the problems and limitations.	Conflict over accessing no-take areas of the park, to develop parts of the archipelago, and to accommodate more people in a limited space.
10	Puerto Libertad and Bahía de Kino, Sonora, Mexico. Coastal.		Management and conservation tools for the marine environment. Interaction within marine environment formulated by NGO and community committee (self-governed).	The project does not contemplate the relationship between terrestrial and marine environments. There is no governmental agency or department that directly deals with the issue.	There is no acknowledgment. Social and ecological connectivity is a relatively new subject for fishermen. COBI has already worked on this, but the authorities are not involved yet.	Conflict between fishers from different communities over the same fishing area.

11	Guaymas, Sonora, México. Island.		A PA covers the terrestrial environment, and fishing refuges (marine conservation tool). By initiative of NGO and fishers, a committee was created to manage the refuges, which promotes integration between both environments.	Scarce governmental presence. Poor allocation of resources for managing the island due to its smaller size.	Fishers (small-scale and sport) and tourism agencies are aware that unmanaged activities are threatening species populations.	Small-scale fishers using gill nets are resistant to no-take zones and future Marine Protected Area (to be established), which bans gill nets.
12	Southeast Saint Lucia. Island.		A PA that includes terrestrial and marine elements. The Management Plan addresses both. Additional institutional arrangements integrate several actors.	There is limited integration at the management level.	Sea moss farmers are particularly aware of the connections.	Farming practices contribute to sedimentation and nutrient loads; lack of sewage treatment from communities is another factor.
13	The southeastern part of the Otavalo municipality, Province of Imbabura, Ecuador. Inland.		Without integrative instruments of terrestrial and marine environments. The case study addresses the terrestrial environment, within which participative spaces have been created.	The geography of the region affects land-sea connectivity (high mountains, volcanos). Lack of integrated institutional instruments for terrestrial and marine environments. Unrecognized ecosystem relations. Lack of studies on interconnections.	The actors identified the ecosystem services that most positively contributed to their human well-being, such as provision of food from agriculture and livestock, fresh water supply, water regulation and purification, soil fertility and erosion control, air quality regulation, and cultural identity, ancient knowledge and sense of place.	Changes in land use and the proliferation of eucalyptus crops are altering the water regulation of the region, which could reduce the flows of nearby rivers and affect the sedimentation processes.

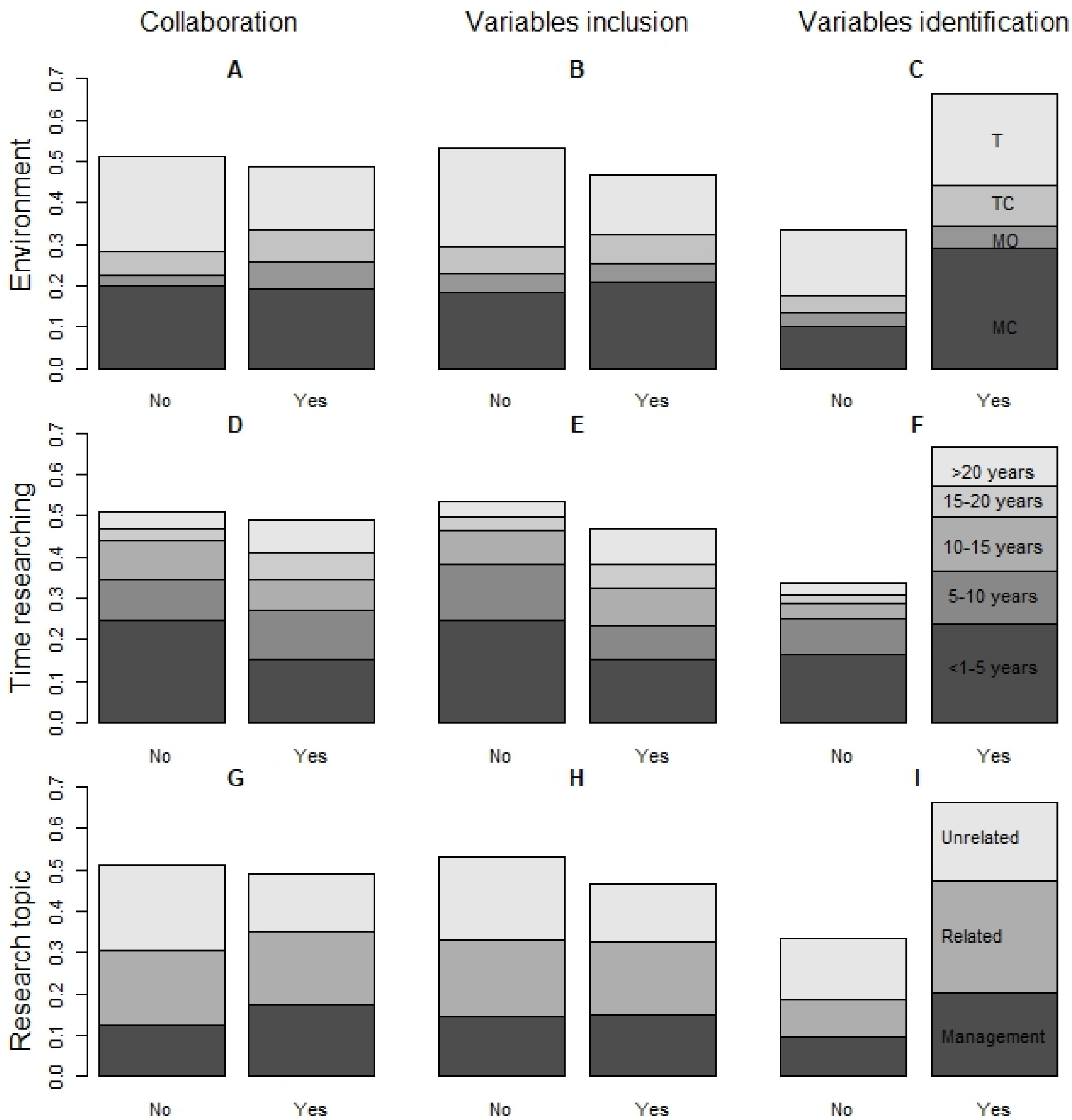


Fig. 1. Extent to which a systemic view is applied by researchers according to the environment in which they are focused (Panels A-C; T = terrestrial inland, TC = terrestrial coastal, M = Marine offshore and MC = Marine coastal), the time they were developing the research (D-F) and the relation of the research topic to land-sea interactions and management (G-I). Panels A, D and G show the collaboration with colleagues working in the other environment (terrestrial or marine as appropriate); B, E and H the inclusion of variables from the other environment in the research; C, F and I the identification of variables from one environment that affect the other. Scale indicates proportion.

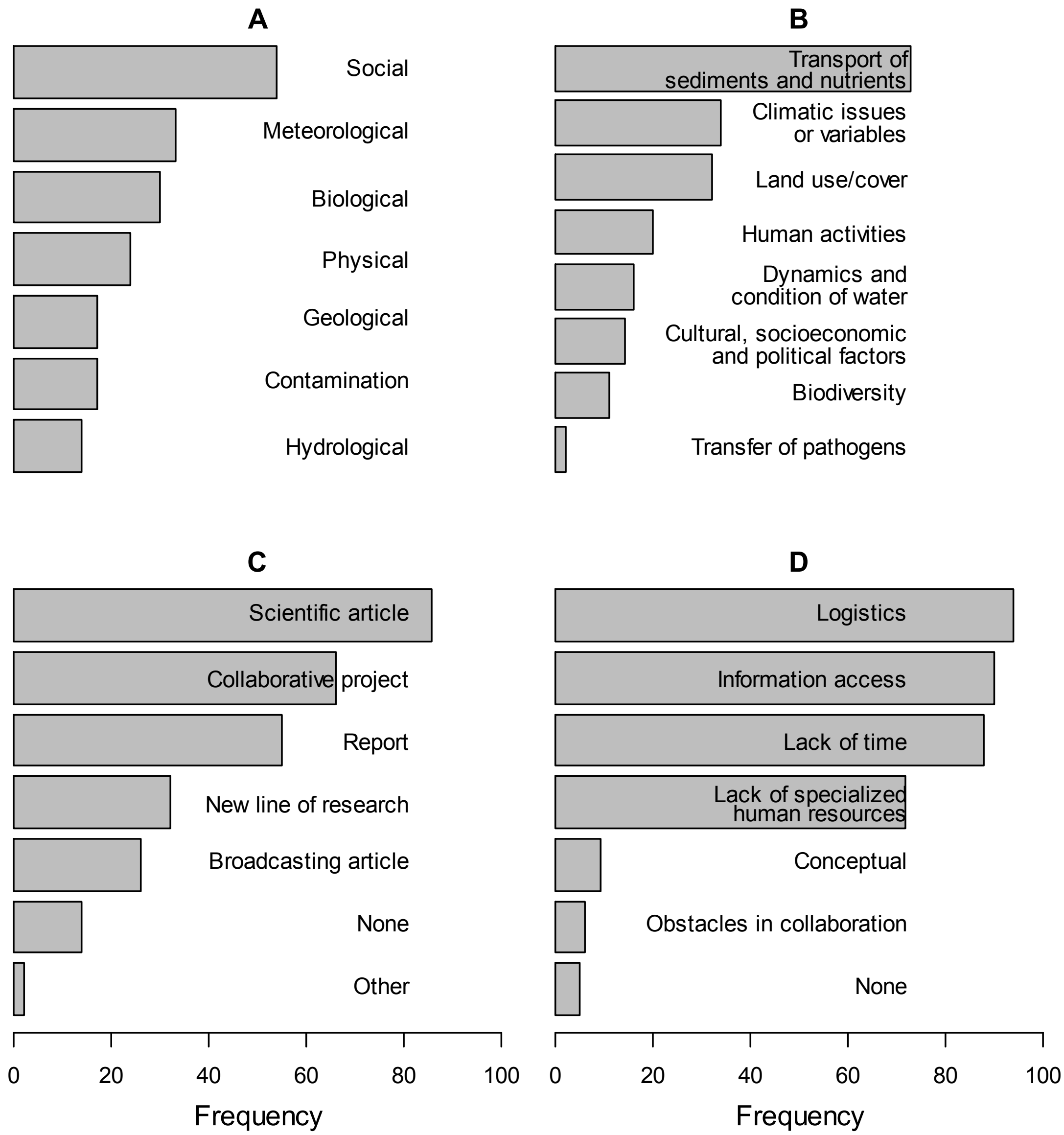


Fig. 2. Variables from the other environment (terrestrial or marine as appropriate) included in research by respondents (A); variables from one environment affecting the other identified by respondents (B); outcome of interactions with colleagues working in the other environment (C); research difficulties in including the identified variables in their studies (D). Scale indicates frequency.

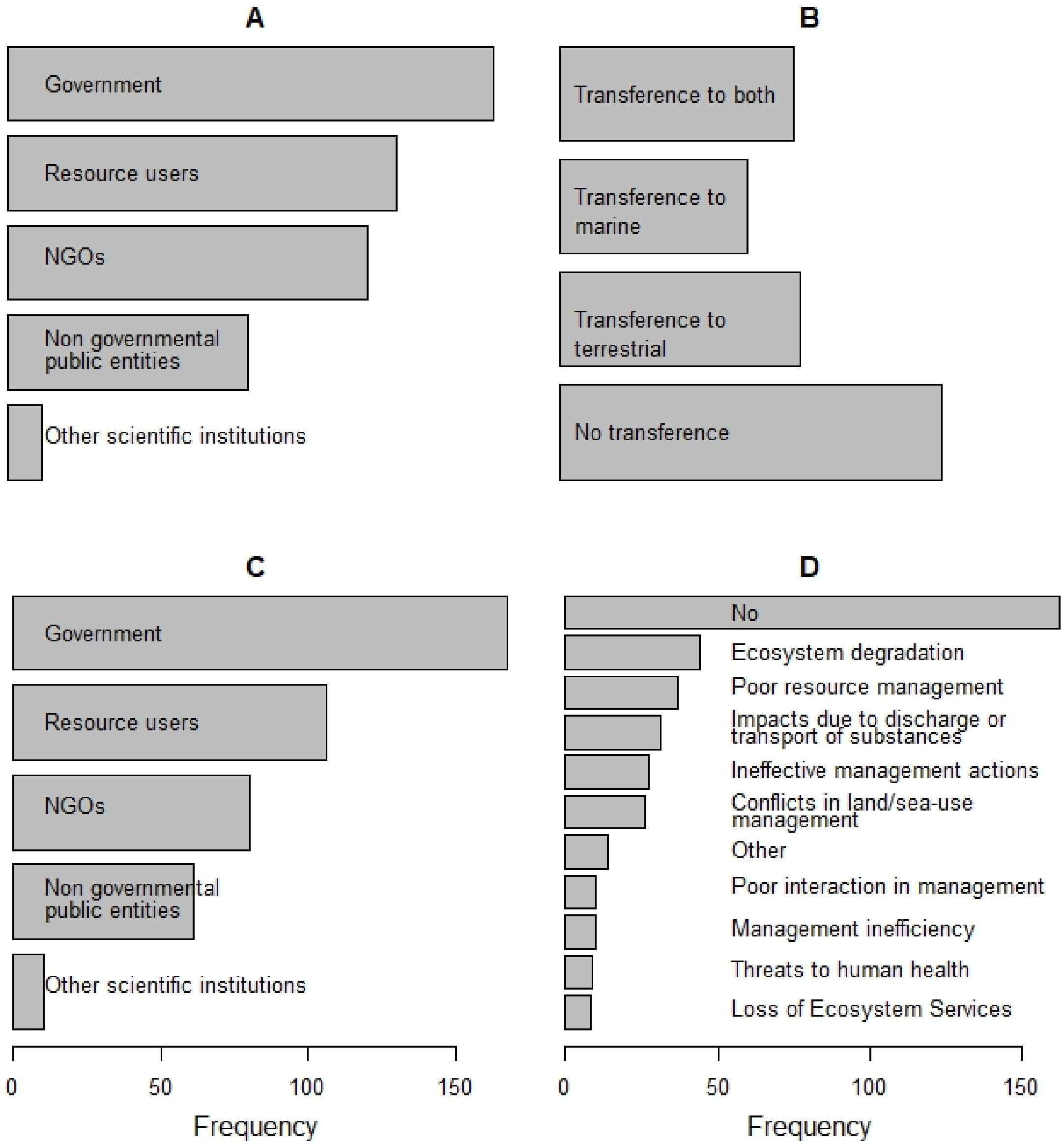


Fig 3. Socialization of science. Sectors involved in participative activities with respondents (A), transfer of research results to stakeholders from different environments (B), sectors to which respondents transfer their results (C), threats or conflicts identified by respondents if the information related to one environment does not reach stakeholders involved in the management of the other environment (D). Scale indicates frequencies.

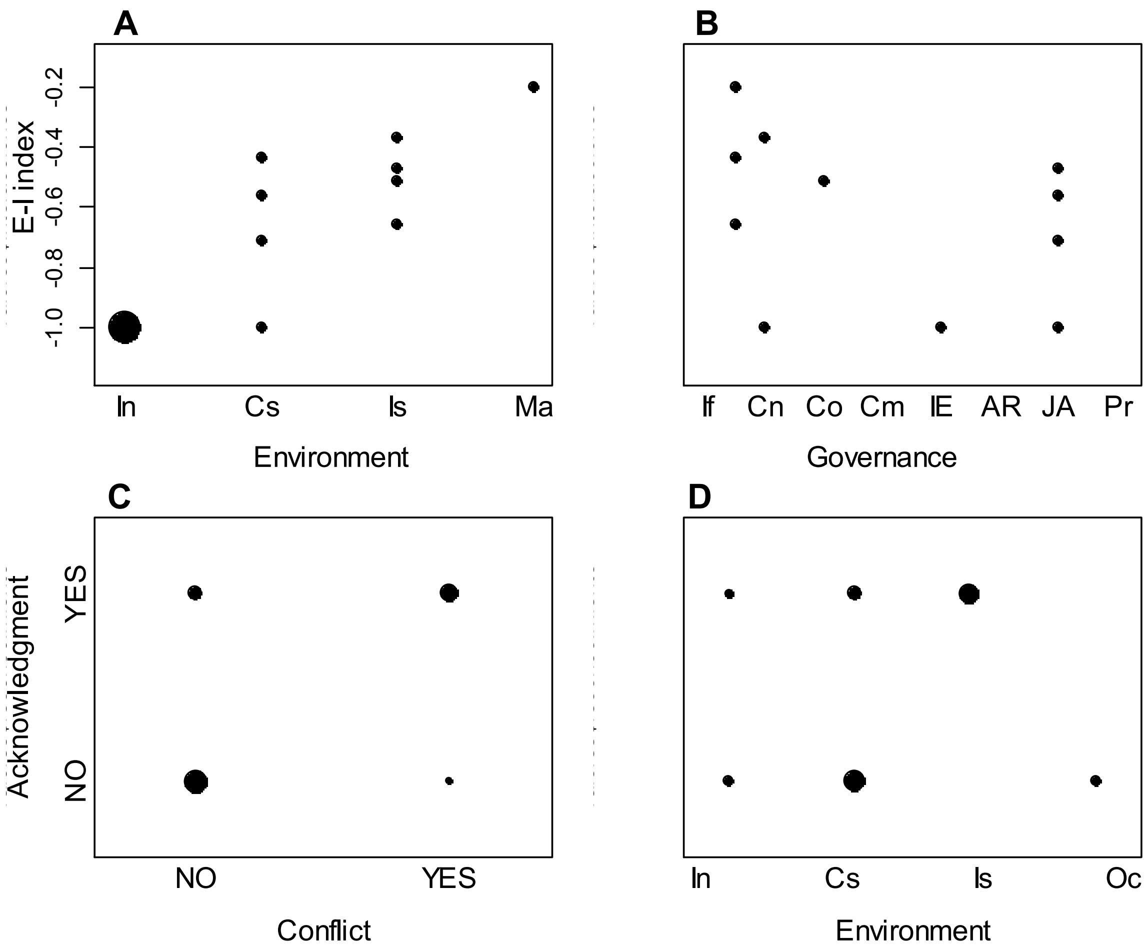


Fig 4. Upper panels show the relationship between the degree of interaction of stakeholders from different environments (land-sea) quantified by E-I index and: (A) type of environment (i.e. Inland= In, Coastal = Cs, Island =Is and Marine = Ma), (B) model of governance (i.e. Informing= If, Consultation= Cn, Cooperation= Co, Communication= Cm, Information exchange= IE, Advisory Role= AR, Joint Action= JA and Partnership = Pr). Lower panels show the relationships between the stakeholders' acknowledgement of ecological land-sea interaction and: (C) the presence of conflicts between stakeholders from different environments (land-sea), and (D) type of environment. Dot size is proportional to the number of cases.

Highlights

Half of Latin American scientists are not addressing the land-sea systems as a whole.

Communication of scientists with stakeholders across environments is deficient

Governance schemes are compartmentalized and do not align with ecological linkages

Institutional instruments and intermediaries' involvement foster holistic governance

Boundary work and trade-offs modeling may mainstream ES concept to policy