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Linking marine and terrestrial ecosystem services through governance social networks analysis in Central Patagonia (Argentina)

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ABSTRACT

The complex relationship among diverse natural factors in a given ecosystem and with society could be not explicitly reflected in governance actions and policy. Social networks are useful tools to characterize these links but few studies include social and ecological nodes. We applied social network analysis to characterize governance and use networks in a coastal socio-ecological system while testing (i) if governance links reflects ecosystem services (ES) use links, (ii) if social links reflect ecological relations between continental and marine ES and (iii) if relations among social actors are associated with their use of and participation in the management of ES. We use structured interviews to build one-mode use and governance networks with social actors and two-mode networks relating social actors and ES. Our results showed cohesive, low density and centralized networks of governance and use. We found that actor–actor links reflect ecological relations between continental and marine environment, but actor–actor relations are weakly correlated with those derived from actor–ES relations, meaning that actors with common interest about ES are no necessarily working together. This paper also shows that social networks are useful to highlight gaps and paths to move the system toward more effective co-management structures.

1. Introduction

The governance of ecosystem services (ES) is usually influenced by unpredictable changes (Folke et al., 2004). Slow or abrupt changes in the environment resulting from unsustainable use of natural resources have led the scientific community to propose a paradigm shift based on the ecosystem approach (Chapin et al., 2010). This approach integrates three principles simultaneously: reducing vulnerability to potential unwanted changes, developing resilience scenarios aimed at finding more desirable paths to shocks and uncertainty (Costanza and Folke, 1997), and transforming undesirable trends into new opportunities for resilience (Walker et al., 2004). The resilience of the ecosystem depends largely on key species that inhabit a particular ecosystem. Proper maintenance of these key species ensures functional diversity of natural cycles and processes necessary for the stability of socio-ecological systems (Chapin et al., 2010).

Under this context, ecosystem governance not only deals with the management of the ecosystem, but also with related social aspects such as decision-making, social interaction and power relations. The necessity to include perspectives from various stakeholders is important for understanding potential strategies for sustainable ecosystem management. It is quite common that stakeholders with different stakes have different perspectives on management strategies (Hauck et al., 2014).

The ecosystems based approach has the potential to lead to a better understanding and management of marine social–ecological systems (Hilborn, 2007). Compared to traditional single-species management, an ecosystem-based or holistic approach is assumed to be the most adequate for adaptive management of the inherent complexity and diversity of a social–ecological system (Ostrom, 2011). Because of the complexity of social–ecological systems, there will remain uncertainty regarding causal relationships within ecological and social systems and their responses to external drivers (Folke et al., 2004). For that reason it is highly recommendable to follow an adaptive process in which actors can learn about uncertainty and non-linearities, in particular when investigating the interconnected feedbacks between continental and marine social–ecological systems (Armitage et al., 2008).

In terrestrial ecosystems, the most relevant change during the last 50 years was the profound modification of the soil towards land for cultivation and the applications of new technologies in

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order to increase the flow of provisioning ES (food, fiber, wood). As result of these transformations, marine social–ecological systems have been also affected due to the increase of erosion, the flow and transport of sediments and organic matter as well as the increase of nutrients which ultimately can generate contamination and eutrophication (Millennium Ecosystem Assessment, 2005).

Despite strong interactions between land uses and coastal ecosystems, land–sea interactions are almost always ignored when designing policies by governments (Beck, 2003). However, recent research has been stimulating an integrated decision-making process to take into account these interactions. Under this context, important progresses are expected in the implementation of the ecosystem based approach if social actors who are using ES and those with the responsibility of managing them are closely related and work jointly in a given area. Nevertheless, little research has been done on this topic in the field of terrestrial and marine social–ecological systems jointly. In addition, although the lack of a policy in which the relationships between actors are managed, it is expected that actors with similar interests using ES will also try to construct social networks to deal with the same problems (Coleman, 1990; Liu et al., 2007).

Social network analysis (SNA) has proven to be useful tool in studying and explaining social phenomena to provide an innovative framework to analyse the social dimension of social–ecological systems (e.g. Bodin and Crona, 2009; Crona and Bodin, 2010; Ramírez-Sánchez and Pinkerton, 2009). Key findings emerging from this work is the important interplay between social capital and leadership for effective resource governance. Examples from documented transitions in natural resource governance show that networks of contacts between user groups and scientists are important for increasing exchange of information, leading to changed mindsets and deeper understanding of critical issues facing management (Meijerink and Huitema, 2010). In addition, SNA is progressively cited as instrumental in enabling coastal communities to adaptively respond to different drivers and to initiate and sustain successful transformations in navigating towards resilient social–ecological systems (Bodin and Crona, 2008). The study of social networks has been motivated by the argument that the various positions occupied by actors within the social structure are related to their access to opportunities and resources (Marín and Berkes, 2010).

In spite of scientists have already studied the influence of social network structures and different initiatives to stimulate the adoption of co-management in complex systems (Armitage et al., 2008; Bodin et al., 2006), it is important to highlight that almost all studies have taken into account only a few number of ES (Bodin and Crona, 2008). Most of the research efforts have been focused on the use of SNA and the identification of users exploiting fisheries resources in coastal communities in order to describe the existence of formal and informal social networks as successful ways of bottom-up community based natural resource management (Folke et al., 2011). In this context, the research by Rathwell and Peterson (2012) is noteworthy because address direct and indirect interactions of institution shearing interests in different ES at the watershed scale using two-mode networks.

In SNA, while one-mode data records ties between nodes of one class, two-mode data records ties between two sets of nodes of different classes, and the corresponding networks are called two-mode networks (Borgatti, 2009). These kinds of data are often referred to as affiliations because reflects co-memberships in organizations or participation in events and ties between organizations through their members. In our case study, two-mode networks allow us to record the relations between ecological and social factors, being ES and social actors the two modes or classes of nodes considered. Similarly to the affiliation example, two mode networks reflect association of social actors through ES that could be compared to associations established directly between social actors which are recorded in one mode networks.

This study explores the relation between existing ES of the study area and social actors by using two-mode networks in order to examine opportunities and treats of the governance system. For that reason, the objectives of this paper are to characterize governance and use network while assessing (i) if governance links reflects ES use links, (ii) if the links among social actors reflect the ecological relations between continental and marine factors and (iii) if relations among social actors are associated with their use of and their participation in the management of ES.

2. Materials and methods

2.1. Study area

The social–ecological system which forms the basis for the analysis in this paper is located in Comarca VIRCH-Valdés, in the NE of Chubut province and Central Patagonia (Argentina, Fig. 1). *Comarca* is an administrative unit created by the provincial government to improve regional productive strategies. The Comarca VIRCH-Valdés concentrates over than 24% of Chubut province population, which mostly inhabits main cities (Trelew, Puerto Madryn and Rawson), and smaller towns (Gaiman, Dolavon and Puerto Pirámiedes).[1] Climate is temperate semi-arid, with an average annual rainfall of 250 mm and high inter-annual variation (Paruelo et al., 1998). Most rural area consists of private properties where extensive sheep ranching for wool production is the main economic activity. Sheep feed on natural pastures and shrubs characteristics of the southern Monte Phytogeographic Province (León et al., 1998). However, this activity is declining due to the drop of prices combined with large droughts, which led to a huge migration from rural to urban areas, stressing the concentration of population in main cities. So most of population is engaged in commercial and administrative activities, and those related with textile industry in Trelew or aluminium production in Puerto Madryn.[2] In this context, some of the causes already identified by the Millennium Ecosystem Assessment (2005) which usually cause the degradation of ES are present in the area: the unplanned economic growth, the demographic changes and the decline of agriculture.

This administrative unit includes tow distinctive areas: the lower valley of Chubut River (VIRCH because of its Spanish name) and Península Valdés. The valley is a highly productive area within a semi-arid region because an extensive irrigation system based on Chubut river waters. It is 90 km long with variable width between 7 and 10 km. This area consists in numerous small private properties which main productions are fruits and vegetables. Producers of the valley usually associate for process and trade of their products.

Peninsula Valdes is a geographic feature unique in the world. It has an area of approximately 350,000 ha and is located between the Gulf of San Matias and Golfo Nuevo at 42°00′42°48′S, 63°32′ to 65°16′W. Its shores are composed of varied coastal geomorphological features including bays, gulfs, cliffs, and beaches that contribute to the aesthetical value of ecosystems. Steppe is the predominant vegetation type of Peninsula Valdes, with low shrubs, grasses, and plants. The waters of the peninsula are valuable natural breeding areas for many varieties of sea birds and large marine mammals, such as whales and sea lions. Peninsula Valdes is home to characteristic species of Patagonian

[1] Last National Census data (2010) available at ⟨http:www.estadstica.chubut.gov.ar/home⟨.

[2] ⟨http:www.estadstica.chubut.gov.ar/home⟩.

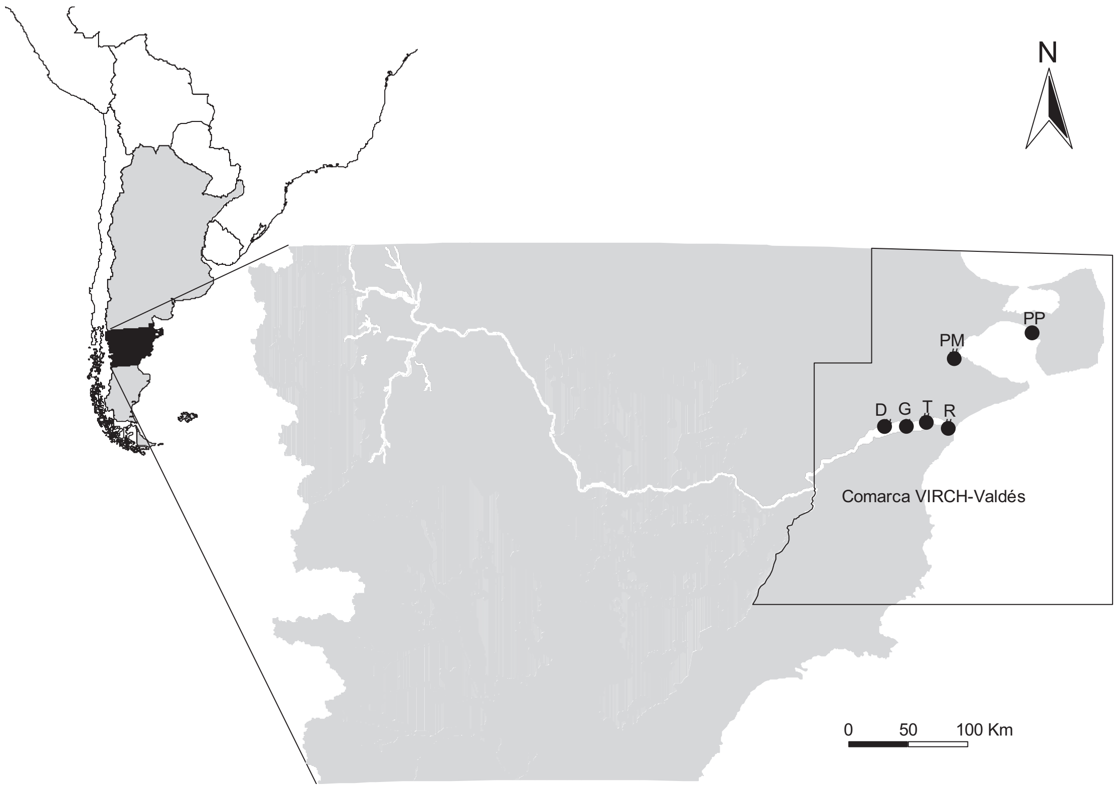

Fig. 1. Map showing the location of study area (Comarca VIRCH-Valdés) and Chubut province which comprise most of the Chubut river valley. With black filled circles are indicated the localities within the study area identified with their names initials D=Dolavon, G=Gaiman, T=Trelew, R=Rawson, PM=Puerto Madryn and PP=Puerto Pirámides.

fauna as guanaco, mara and grey fox and 181 species of birds as well as other marine and terrestrial species of great biodiversity value. To protect the rich fauna and landscape of this area, Peninsula Valdes was recognized in 1999 by the UNESCO as a World Heritage site. This area provides ideal conditions for the development of economic activities such as agriculture, tourism, whale watching, commercial and recreational fishing, and surfing, all of which generate significant economic and social benefits for the country. For example, in 2013 over 291,139 tourists visited Península Valdés.[3]

2.2. Social network analysis

We applied social network analysis to a coastal socio-ecological system from Comarca VIRCH-Valdés (Central Patagonia). We defined the system boundaries based on the ES framework, and the geographical and administrative boundaries of the region tacked as a case study.

The actors considered were organizations or institutions representing a group of individuals which are ES users or involved in its management within the study area. We built the lists of actors (Appendix A) based on available documents of creation and activity regulation of organizations, provincial and municipal laws, scientific and grey literature. Based on Millennium Ecosystem Assessment (2005) definition and CICES[4] classification we build a list of ES, splitting in two classes (continental and marine) when appropriate (Appendix B).

We researched and registered relationship between actors (actor–actor) or actors and ES (actor–ES), and complemented the actor's list using structured interviews with representatives from each actor. We performed 52 interviews to people in head or communication charges of 48 institutions (actors). More than one interview was performed for each institution in case the information required was managed by more than one person. Representatives of 10 actors reject to respond the interview and the information about these actors was extracted from web pages. Final list included 58 actors comprising governmental and non-governmental public entities, chambers of commerce, producers' associations, NGOs, knowledge production institutions and networks of institutions, from all localities within the study area (Appendix A).

2.2.1. Questionnaires and interviews

First, interviewees were queried to identify from a list of ES those to which their organization was related by: (a) use of ES, (b) use regulation or management of ES. Second, to select from a list of actors those with whom their organization were related, describing the relationship choosing options (Appendix C). With this information we built adjacency matrices actor–ES and actor–actor for use and governance relationships separately (Fig. 2). We considered that actor–ES use relation existed if the organization or the portion of the population represented have ever used a given ES for their activities or affected it by them. This type of relation differs from governance because the organization does not create rules for the use, nor made negotiations to modify the supply, neither set policy about ES use or management. Regarding regulation and support services, we considered a link when an actor increased or decreased a given ES demand (e.g. waste

[3] ⟨http://aanppv_nueva.peninsulavaldes.org.ar/?page_id=564⟩ [Acceded 17/08/2014].

[4] ⟨htto://cices.eu/⟩.

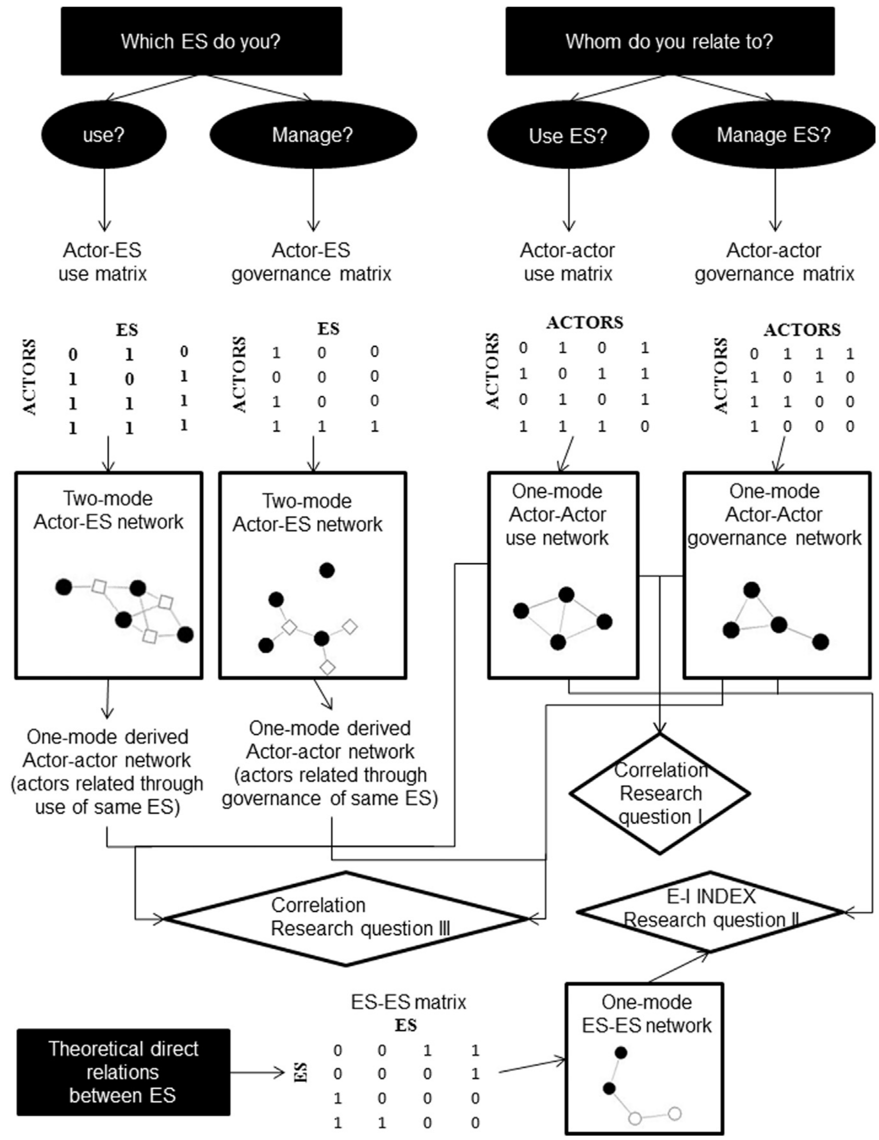

Fig. 2. Diagram showing the sources of information to build social networks and the analysis performed to answer each research question.

production or waste treatment). We considered that an actor–actor use relation existed if one of them provided or managed a given ES whereas the other actor consumed, used it or even if both actors used it together. However if two actors were related to modify the supply, change, set rules or manage a given ES, we considered that existed a governance relationship.

2.2.2. Network building and analyses

We built one-mode use and governance networks including actors and two-mode networks with actor–ES relations (Fig. 2). To characterize one-mode networks we calculated basic properties: density, centralization, degree, betweenness, geodesic distance and number of possible paths (Table 1). We also identify the five actors with highest degree and betweenness accounting for more than 20% of accumulated degree/betweennes, and performed a correlation test between actor's degree and betweennes to evaluate if actors with high degree also had high betweenness. To evaluate if governance links reflects ES use links we performed (1) a Quadratic Assignment Procedure (QAP) correlation (Prell, 2012), testing the association between the two networks (Fig. 2), (2) a correlation test between actors' degree of use and governance networks. To characterize two-mode networks we calculated only density, actor degree and ES degree as basic properties, and we did the same network analysis to evaluate if governance links reflects ES use links as we described for one-mode networks.

To evaluate if the links among actors reflect the ecological relations between continental and marine ES we built a one-mode network with direct ES–ES relations based on information on Millennium Ecosystem Assessment (2005) about these relations (Fig. 2). We considered that a relation existed if one ES use or modification could directly affect the other ES in the relation. We also classified actors in continental and marine considering an actor continental or marine if it was predominantly related with continental or marine ES respectively. Finally, we calculated the E–I index (external–internal index; Krackhardt and Stern, 1988) for ES–ES, actor–actor use and governance networks blocked by environment, and tested if were smaller than expected by chance with permutation tests of 10,000 iterations. The E–I index measures the extent to which macro-structures, like the blocking by environment, "cluster" the interaction patterns of nodes who fall within them comparing the numbers of ties within groups and between groups (Hanneman and Riddle, 2005). The index ranges

Table 1
Description of basic properties calculated to characterize social networks.

Basic property	Measure
Density	Density is defined as the number of existing links divided by the number of possible ties. It indicates how connected is a population
Centralization	Centralization indicates the tendency in the network for a few nodes to have many links, e.g. a wheel-star structure in which one central node is connected with all other nodes (degree $= n-1$) whose are not connected between them (degree $=1$). Centralization expresses the degree of inequality or variance in the network as a percentage of that of a perfect wheel-star network of the same size
Degree	The degree of a node, also called degree of centrality indicates the number of links a node has (Freeman, 1979). A high degree of centrality for an individual node indicates that it has many links compared to other nodes and a central (powerful) position in the network
Betweenness	Betweenness is the measure that indicates how much a node is located in the path between other actors or how much a node connects other nodes with each other (Freeman, 1977). This measure can be applied to individual nodes, and can then be used to identify actors that contribute most to linking the network
Geodesic distance	The geodesic Distance measures the number of ties that separate two actors. If two nodes are directly connected, the distance is one. If these two nodes are separated by one node, the distance is two. These measure is related with the network density and indicates how easy flow the information between two nodes
Number of possible paths	The Number of possible measures in how many different ways is possible to reach from one node to other node. It quantifies the redundancy in the network and indicates the possibilities of information flow when obstacles arise

from -1 (all ties are internal to the group) to $+1$ (all ties are external to the group). In our case, we expect values of the index from -1 to 0 if ES from the same environment are more related among them than with ES from the other environment, and similar values for actor–actor use and governance networks if the links among actors reflect the pattern of ecological relations.

To assess if the links among actors reflect their relations with ES, we derived one-mode actor–actor networks from two-mode networks relating social actors through their use or governance of the same ES. We test the association of derived actor–actor networks with original actor–actor use and governance networks obtained from interviews performing QAP correlations (Fig. 2). All SNA was performed using statnet suit of packages (Handcock et al., 2014, 2008) in R Core Team (2013).

3. Results

3.1. Actor–actor relations

Use and governance relations among social actors showed similar structures with cohesive and centralized patterns (Fig. 3). Although most actors were related, density was moderately low (Table 2), lower than expected by networks size ($p<0.001$ for both networks).

Centralization was higher than expected given the number of dyads ($p<0.001$ for both networks). Mean degree and betweenness were moderate with high variation in both networks, indicating that few actors were related with many others (Table 2). In addition, actors with highest degree showed also the highest bettweenness (rho $=0.916$, $p<0.001$, for use network; rho $=0.931$, $p<0.001$, for governance network). Both networks were well connected and compact given that the average geodesic distance among actors was quite small, with several paths to reach another actor and the maximum geodesic distance was 4 (Table 2).

Although use and governance networks presented similar structures they were weakly correlated (QAP correlation $=0.430$, $p<0.001$). Governance network was less dense and more centralized than use network. Mean values and variation of other basic network properties showed also this trend (Table 2). Actors have similar degree in both networks (rho $=0.576$, $p<0.001$), being the most influent actor the Provincial Government (A1) in both networks (Tables 3 and 4).

3.2. Actor–ES relations

Use and governance relations among social actors and ES showed similar structures (Fig. 4): a core group of actors related with most ES, a periphery group related with some ES and a group of isolated actors. Density was low in both networks but in average actors were related with more than a fifth of the ES (Table 5). However, use and governance networks were weakly correlated (QAP correlation $=0.34$, $p<0.001$). The use network was slightly more dense and centralized than governance network. The main difference between the actor–ES networks was the identity of actors in each of the groups described above (rho $=0.111$, $p=0.407$).

Municipalities were the actors with the highest use of ES however they were not the actors with the highest participation in governance of ES, with the exception of Municipality of Puerto Madryn and Gaiman (Tables 4 and 6). Among the actors related with the governance of more ES we found the Provincial Government, a research institute and a NGO. Regarding ES, the most used were in general the ones with the most actors involved in their governance (rho $=0.558$, $p<0.001$). Water provision and waste mediation were the ES which receive most attention(Tables 6 and 7). However, we observed some discrepancies between use and governance, like food provision and cultural services related with intellectual interaction, being used by many actors but with few participating in its governance.

3.3. Correspondence between social and ecological relations

One-mode network reflecting theoretical direct relations between ES shows few ties between marine and continental ES (Fig. 3, ES–ES). Relations of direct effects were more frequent within marine or continental ES than between these groups (E–I index $=-0.608$, $p<0.001$). Relations among social actors classified in marine or continental reflected the same pattern regarding use (E–I index $=-0.311$, $p<0.001$) and governance of ES (E–I index $=-0.342$, $p<0.001$), but ties between marine and continental actors are relatively more frequent. However, most social actors related through use or governance of the same ES, as derived from actor–ES two-mode network, were not related in one-mode networks representing relations declared by actors during interviews, being the correlation for use relation lower (QAP correlation $=0.183$, $p<0.001$) than for governance relations (QAP correlation $=0.393$, $p<0.001$).

4. Discussion

4.1. Actor–actor relations

The characterization of actor–actor use and governance networks by means of basic properties calculation showed that

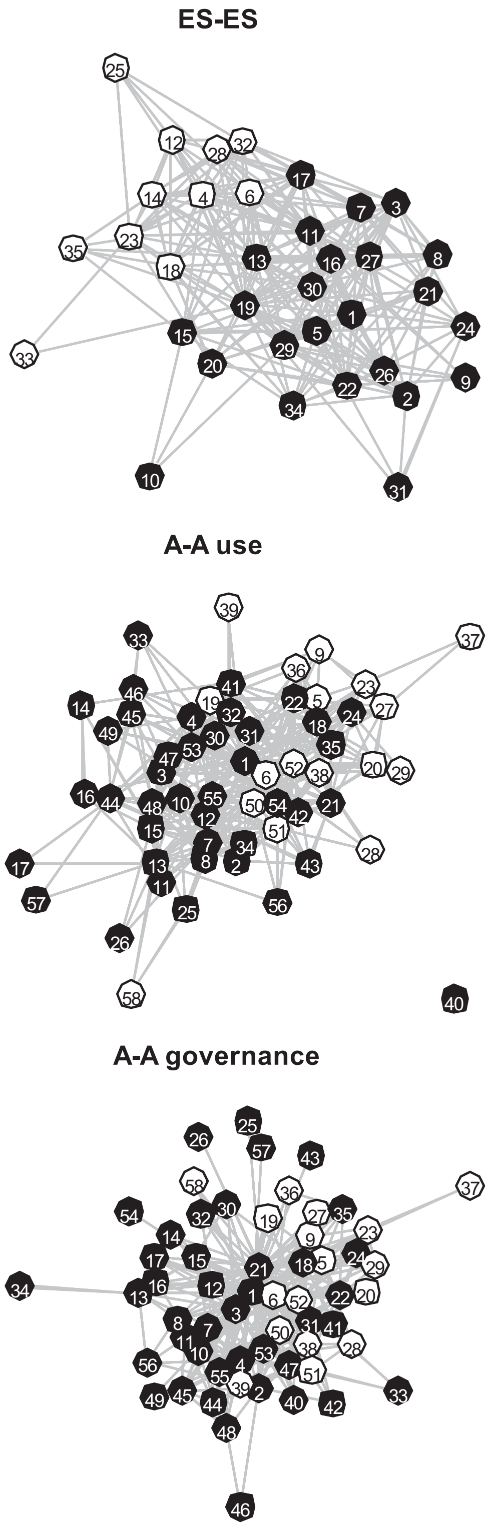

Fig. 3. ES direct effect network (ES–ES), actors use network (A–A use) and governance network (A–A governance) showing nodes associated with marine environment (empty circles) and continental environment (filled circles).

networks were cohesive, had low density and high centralization. Despite low density, the cohesion of both networks, could indicate that exist trust and willingness to cooperate, basics components of social capital (Pretty, 2003), and present connections should be the basis to strengthen relationships and institutions, building new governance schemes. The low density is probably because actors of the same type or with sharing interests are not working together.

Table 2
Basic properties scores of actors use (A–A use) and governance (A–A governance) networks. Degree, betweennes, geodesic distance and possible paths are informed as mean and standard deviation in parentheses.

	A–A-use	A–A-governance
Density	0.200	0.18
Centralization	0.46	0.73
Degree	22.83 (15.53)	20.14 (18.85)
Betweenness	26.55 (51.08)	26.67 (88.41)
Geodesic distance	1.93 (0.67)	1.90 (0.59)
Possible paths	3.44 (4.24)	2.52 (1.97)

Table 3
Actors with highest degree and betweenness in actors use (A–A use) and governance (A–A governance) networks.

A–A use		A–A governance	
Degree	Betweenness	Degree	Betweenness
A1	A1	A1	A1
A6	A6	A21	A21
A52	A13	A3	A3
A31	A52	A6	A52
A55	A53	A52	A6

According statements of some interviewees, this could be happening due to competence between similar institutions to demonstrate achievements and/or get financial resources. Similar result was also reported for fishing associations in Chile, where conflicts due to competence and poaching make difficult the strengthening of horizontal relationships between actors (Marín and Berkes, 2010). However, a low density does not necessarily reflect absence of collaborating work because actors considered here are groups of individuals working with common interests and we detected 58 actors in the studied area. In addition, networks are centralized in structure and power distribution, given that actors with most links (high degree) also are linking other actors (high betweenness). Generally these powerful actors are source of resources or authorities (provincial government, municipalities) or knowledge production institutions representing a top-down structure in which central actors have resources and periphery actors require them. Similar structures have been reported in other systems (Bodin and Crona, 2008; Ernstson et al., 2008; Marín and Berkes, 2010) and they may be related with undesired features like underrepresentation of peripheral actors, inappropriateness to solve complex problems and vulnerability to removal or dysfunction of central actors (Bodin and Crona, 2008). However, the structures described here are more complex because there are different types of actors and multiple social functions (research, governance, administration, production, commerce, services, etc.). This feature could be counterbalancing some disadvantages of centralization given that heterogeneity is part of new governance models to lead with complex problems (Dietz et al., 2003; Duit et al., 2010). In combination with closeness, these features have been related with system adaptability (Sandström and Rova, 2010). Centralized structures of governance may be effective during crisis or change periods and could be related with collective actions but it depends on entrepreneurship, representativeness and ability to coordinate and manage information of central actors (Bodin et al., 2006; Bodin and Crona, 2008). A shift of the system towards more balanced and participative structures could be leaded by central actors, mainly the provincial government which is in that position because it is the legal authority and possess domain of natural resources according to the law. Recently, the provincial government has established participation instances which may stimulate

Table 4
Name and attributes of actors with highest degree or betweenness in actors and actor–ES networks.

ID	Name	Type	Locality
A1	Gobierno provincial	Governmental-province	
A3	Instituto Provincial del Agua	Governmental-province	
A6	Minicipalidad de P. Madryn	Governmental-municipality	P. Madryn
A7	Minicipalidad de Trelew	Governmental-municipality	Trelew
A8	Minicipalidad de Rawson	Governmental-municipality	Rawson
A9	Minicipalidad de P. Piramides	Governmental-municipality	P. Pirámides
A10	Minicipalidad de Gaiman	Governmental-municipality	Gaiman
A13	Coop. De servicios de Rawson	Non-governmental public entity	Rawson
A21	Fundación Paragonia Natural	NGO	P. Madryn
A31	Cámara de Comercio de P. Madryn	Chamber of commerce	P. Madryn
A52	CENPAT	Knowledge production institution	P. Madryn
A53	INTA	Knowledge production institution	Trelew
A55	INTI	Knowledge production institution	Trelew

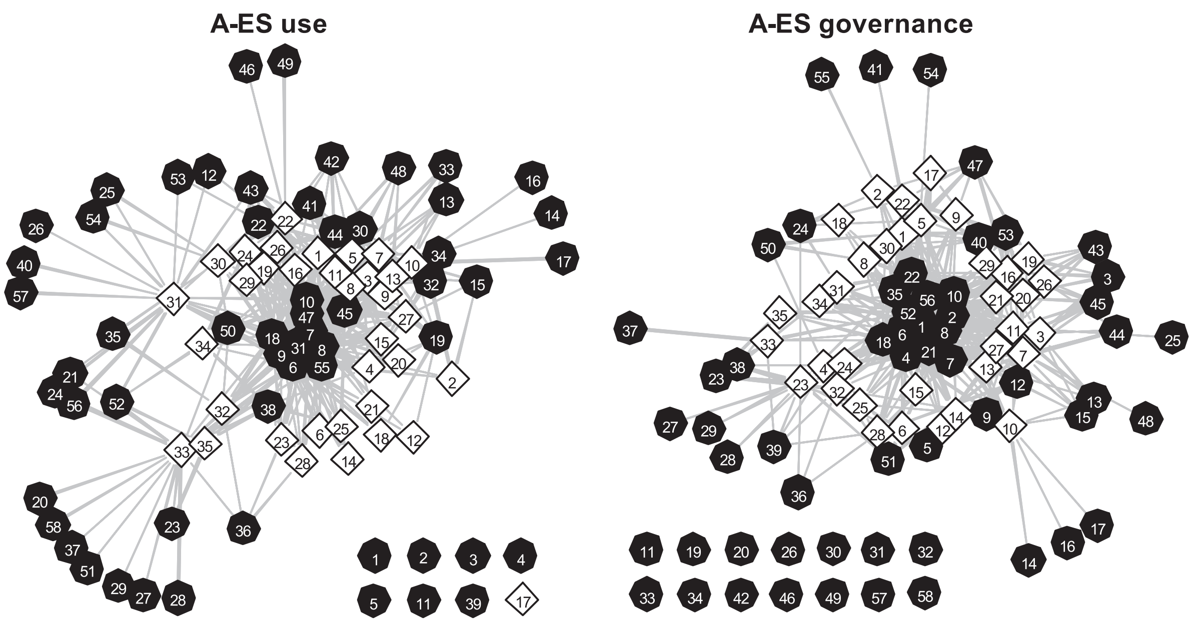

Fig. 4. Two-mode use (A–ES use) and governance (A–ES governance) networks show actors as filled circles and ES as empty diamonds.

Table 5
Density and mean degree scores of actors–ES use and governance networks. Standard deviation of mean degree indicated in parenthesis.

	Actors–ES use	Actors–ES governance
Density	0.20	0.18
Actor degree	6.90 (8.56)	6.19 (7.63)
ES degree	11.43 (6.11)	10.26 (4.35)

Table 6
Actors and ES with highest degree in actors–ES use and governance networks.

Actors use	Actors gov.	ES use	ES gov.
A6	A6	S11	S7
A8	A52	S7	S11
A9	A1	S31	S3
A7	A21	S1	S13
A10	A10	S33	S23

connections among users and co-management, like fishing and desertification technical committees and watershed committee. Nonetheless, since the final decision still remains with the government it may happen that participation of users is just a formality, transforming these instances in disincentives. Otherwise, a bottom-up mediated shift could happen if related institutions gather in regional federations to counterbalance government power (Marín and Berkes, 2010). In the studied system that possibility seems not plausible because although some actors stated to be related to federations, the action range of the federations is national and they have minor intervention in regional ES management.

Use and governance networks showed similar structures but governance network was more centralized than use network. This is consistent with findings regarding provincial government as the authority over most ES. In addition, we found weak correlation among networks, probably due to coincidence in central actors' links and differences in alliances among peripheral actors. The links of central actors represent regulation or advice for the use of ES by other actors in use network, and negotiations of users with authority in governance network. However, a remarkable difference is found regarding governance network, as a NGO resulted to be a central actor indicating a heterogeneous governance structure of the system in terms of institutions and functions.

4.2. Actor–ES relations

Use and governance networks were similar in structure with each actor related with several ES, and each ES used or regulated by several actors. However, a disagreement is found between actors using a given ES and actors participating in its governance.

Table 7
Name and classification according CICES of ES with highest degree in actors–ES use and governance networks.

ID	Section	Division	Ecosystem service
S1	Provisioning	Nutrition	Food from cultivated crops and reared animals
S3	Provisioning	Nutrition	Water for drinking
S7	Provisioning	Materials	Water for non-drinking purposes
S11	Regulation & maintenance	Mediation of waste, toxics and other nuisances	Mediation of waste, toxics and other nuisances by biota and continental ecosystems
S13	Regulation & maintenance	Mediation of waste, toxics and other nuisances	Dilution by atmosphere, and freshwater
S23	Regulation & maintenance	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection in marine ecosystem
S31	Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Intellectual and representative interactions with continental environment
S33	Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Intellectual and representative interactions with marine environment

Additionally, some of the most used ES were not the ones with more actors involved in their governance. This situation could cause a mismatch between users' stakes and management decisions. The incorporation of users in discussion of rules is critical to induce compliance of rules and encourage adaptation and change processes (Dietz et al., 2003).

Municipalities use many ES because they represent the community in each town, but as governmental institution they are the authority over few ES. In general they do not implement policies to regulate the use or impacts over ES under management within their range (i.e. to prevent diminishing of water retention by soil or pollution conducted by storm drains improving urban planning). Instead, within actors provincial government, a NGO and a research institute are the most active actors participating in ES governance. Moreover, these three institutions were central actors in actor–actor networks, indicating that they may lead and coordinate interactions of other groups of actors related with a single or a smaller group of ES. These groups could include associations of producers and chambers of commerce whose relation with ES is restricted by their activities and stakes.

Water supply ES (S7) and mediation of waste (S11) had more actors involved in their use and governance than the remaining ES. The attention paid to water supply is in agreement with the importance of this ES in an arid environment in general and in particular to the valley and associated cities. The mediation of waste had many actors related, because it is also a demanded service in urban areas with six towns within the study area. Moreover because the implementation of a new waste management plan to eradicate open dumps developed by municipalities and other actors within these towns. The ES Dilution of waste and toxins by atmosphere and freshwater (S13) and Lifecycle maintenance, habitat and gene pool protection in marine ecosystem (S23) were among the five ES with highest number of actors involved in its governance. This result shows the commitment of society with environmental care, in special with those aspects traditionally related with conservation and interaction with nature through tourism and outdoor activities performed within the study area. It also highlights the value given to marine environment and its biodiversity, for which this region is well known worldwide.

Cultural services related with intellectual interaction were among the most used, because there are several research institutes and universities as actors, but also because several actors stated organize training and awareness activities. This is a desirable scenario to develop adaptive management actions and to shift the system to power balanced structures of co-management, both supported by information sharing and social learning as component of social capital (Pretty, 2003; Pahl-Wostl et al., 2007). In addition to the presence of several knowledge production institutions, the central position they showed in governance structure is important given the relation between ES provision and knowledge leadership (Kenward et al., 2011).

The ES Food from cultivated crops and reared animals (S1) was used by many actors, which is congruent with the high number of associations of producers within the valley, however not many were involved in its governance. This result could indicate a trend to remediate the effects (like water quality and supply) but not the origin of degradation of ES which frequently starts with overexploitation of land in arid ecosystems (Millennium Ecosystem Assessment, 2005). A similar situation was reported in Canadian watershed management, where agricultural municipalities were engaged in fewer activities concerning water quality even when agricultural activities originates most water problems (Rathwell and Peterson, 2012).

4.3. Correspondence between social and ecological relations

Marine regulation of continental climate, or changes in marine water quality and diversity of marine communities as consequence of human activities developed in continental environments, like inadequate agricultural practices or waste generation, are some examples of the relations between marine and continental environments through ecological processes and the ES provided by them. According to our results these environments are directly related only by few ES which are affected or affect other ES of the same environment like in a cascade effect. This general pattern of ecological relations are reflected in social links between actors given that actors classified as marine or continental have more links with actors of the same group than with actors of the opposite group, being few actors who connect both groups. The communication among actors related with different environments is an important component of social capital (Pretty, 2003) that could contribute to prevent or detect effects of activities in one environment over the other and to coordinate actions (Bodin et al., 2006; Bodin and Crona, 2008). However, we also found that actor–actor relations are weakly correlated with those derived from actor–ES relations, meaning that actors with common interest about ES are no necessarily working together. This result highlights a mismatch between incentives defining relations among actors and the ecosystem based management, in concordance to the attention addressed to consequences rather than causes discussed in the previous section. The absence of connections and structures grouping actors with stakes in the same ES could hinder the development of tacit knowledge, reducing the collective capacity to adapt to change (Bodin et al., 2006; Bodin and Crona, 2008) and agreement achievement on resource regulation (Bodin et al., 2014). In contrast, the connections among actors related with different ES could enhance the information flow, a positive aspect of heterogeneity in governance structures (Dietz et al., 2003; Duit et al., 2010; Sandström and Rova, 2010) as discussed above (see Section 4.1). However, it is important to highlight that to detect possible synergies and trade-offs, actors linked with related ES should be connected. In addition, if observed connections were established guided by other incentives than ES management, feedback information linking different ES could be disregarded, missing opportunities for adaptive management. In this context the misfit between social and ecological relations hampers the ability to take into account complexities in ES interactions, diminishing the success probability of policies and management practices to avoid undesired impacts over marine environment by overlooking cross-boundary effects on land use or agricultural management (Liu et al., 2007).

5. Conclusions

Structural characteristics related with resilience and management success like heterogeneity and cohesion are present in use and governance networks. These characteristics of the governance structure offer opportunities for information flow, social capital building and the construction of management strategies that benefit multiples stakes. Centralization of power in few actors from different sectors can also represent an opportunity for structural improvement through institutional strengthening and network reorganization if key actors stimulate decentralization and interaction in cohesive groups that could develop specialized knowledge, developing bridging functions. Reorganization processes would also address a better fit of relations among actors to ecological patterns, strengthening relations among actors with stakes in the same ES or related ES in order to prevent the main threats of the actual governance system: inability to agreed management actions and to take into account complexities in ES interactions, misrepresentation of users' stakes in ES management, poor coordination and loss of valuable information to enhance synergies and prevent trade-offs.

Social Network Analysis was a useful tool to detect inconsistencies between use and governance structures, and particularly two mode networks helped to identify central ES for stakeholders and gaps in governance of highly used ES. This approach highlights discrepancies between actor–actor relations and those expected according actor–ES relations that were not reported before. Further research is needed to clarify incentives shaping social networks given this mismatch and consequences over the effectiveness of ES management.

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Appendix A. List of actors and attributes

ID	Name	Translated name or description	Type	Environment	Town*
A1	Gobierno provincial	Provincial government	Governmental	C	Chubut
A2	CORFO	Provincial corporation for regional development	Governmental	C	Chubut
A3	Instituto Provincial del Agua	Water provincial institute	Governmental	C	Chubut
A4	SENASA	National Service for food health and quality	Governmental	C	Chubut
A5	Prefectura Naval Argentina	Marine and fresh water police	Governmental	M	Chubut
A6	Municipalidad Puerto Madryn	Municipality of P. Madryn	Governmental	M	P Madryn
A7	Municipalidad Trelew	Municipality of Trelew	Governmental	C	Trelew
A8	Municipalidad Rawson	Municipality of Rawson	Governmental	C	Rawson
A9	Municipalidad Puerto Piramides	Municipality of P. Pirámides	Governmental	M	P Pirámides
A10	Municipalidad Gaiman	Municipality of Gaiman	Governmental	C	Gaiman
A11	Municipalidad Dolavon	Municipality of Dolavon	Governmental	C	Dolavon
A12	Servicoop	Cooperative for electricity, water and sewer service provision	Non-governmental public entity	C	P Madryn
A13	Coop. De servicios de Rawson	Cooperative for electricity, water and sewer service provision	Non-governmental public entity	C	Rawson
A14	Coop. Electrica de Pto piramides	Cooperative for electricity and safe water provision	Non-governmental public entity	C	P Pirámides
A15	Coop. Electrica de Trelew	Cooperative for electricity, water and sewer service provision	Non-governmental public entity	C	Trelew
A16	Cooperativa electrica limitada de Gaiman	Cooperative for electricity provision	Non-governmental public entity	C	Gaiman
A17	Cooperativa de servicios publicos Dolavon	Cooperative for electricity provision	Non-governmental public entity	C	Dolavon

A18	Administradora peninsula Valdes	Administration board of Península Valdés proteted area	Non-governmental public entity	C	P Madryn
A19	Administracion Portuaria de Puerto Madryn	Administration board of P. Madryn harbor	Non-governmental public entity	M	P Madryn
A20	Fundacion Ecocentro	Foundation for cultural change relative to ocean perception by means of education, science and art	NGO	M	P Madryn
A21	Fundacion Patagonia Natural (FPN)	Foundation for wilderness protection and responsible use of natural resources	NGO	C	P Madryn
A22	Fundacion Vida Silvestre Argentina (FVSA)	WWF argentine office	NGO	C	P Pirámides
A23	Instituto de conservacion de Ballenas (ICB)	Institute for whales and marine ecosystem conservation	NGO	M	P Pirámides
A24	Wildlife Conservation Society (WCS)		NGO	C	P Madryn
A25	Fundacion Onda Verde	Foundation for environmental education and awareness	NGO	C	Trelew
A26	Fundacion Patagonia Tercer Milenio	Foundation for energetic sustainability	NGO	C	Trelew
A27	Fundacion Tierra Salvaje (WEF)	Wild Earth foundation	NGO	M	P Pirámides
A28	Centro Desarrollo y Pesca Sustentable (CeDePesca)	Centre for Development and Sustainable Fisheries	NGO	M	Chubut
A29	Foro para la conservacion del mar patagonico y areas de influencia	Forum for the conservation of Patagonian sea	NGO	M	Chubut
A30	Camara de Industria y Comercio del Este del Chubut (CICECH)	Industrial and commerce chamber of Eastern Chubut	Chamber of commerce	C	Trelew
A31	Camara de Comercio Industria y Produccion de Puerto Madryn (CAMAD)	Chamber of Industry, commerce and production of P. Madryn	Chamber of commerce	C	P Madryn
A32	Camara Industrial de Puerto Madryn (CIMA)	Industrial chamber of P Madryn	Chamber of commerce	C	P Madryn
A33	Camara de Industrias Laneras de la Patagonia	Chamber of woolen industries of Patagonia	Chamber of commerce	C	Trelew
A34	Camara de Industria y Comercio de Rawson	Chamber of industry and commerce of Rawson	Chamber of commerce	C	Rawson
A35	Asociacion de Agencias de Viajes de Peninsula Valdes	Association of tourism agencies of Península Valdés	Association of users	C	P Madryn
A36	Asociacion de Operadoras de Buceo	Association of dive operators	Association of users	M	P Madryn
A37	Asociacion de Guias Balleneros de Peninsula Valdes	Association of whale watching operators of Península Valdés	Association of users	M	P Pirámides
A38	Asociacion de Pescadores Artesanales	Association of artisanal fishermen	Association of users	M	P Madryn
A39	Red de Fortalecimiento para la Maricultura Costera Patagonica	Network for coastal aquaculture strengthen	Network of institutions	M	P Madryn
A40	Red para la Conservacion de los Ecosistemas Fluviales de la Patagonia	Network for fluvial ecosystem conservation in Patagonia	Network of institutions	C	P Madryn
A41	Propietarios de Predios Rurales de Peninsula Valdes (ProPenVal)	Association of owners of rural properties within Península Valdés	Association of users	C	P Pirámides
A42	Asociacion de Productores Agroecologicos	Association of organic food producers	Association of users	C	P Madryn
A43	Fundacion Ceferino	Educational institution	NGO	C	P Madryn
A44	Cooperativa de 28 de julio productora de alfalfa (COOPALFA)	Cooperative of farmers for pellet production	Association of users	C	Dolavon
A45	Cooperativa Agropecuaria e Industrial Valle del Chubut Ltda.	Agricultural and industrial cooperative from chubut valley	Association of users	C	Gaiman

A46	Asociacion de productores apicolas del VIRCH (APAVIRCH)	Association of beekeepers from VIRCH	Association of users	C	Gaiman
A47	Sociedad Rural Valle del Chubut	Rural society of Chubut valley	Association of users	C	Trelew
A48	Cooperativa Agricola Tres Sauces	Cooperative of beekeepers	Association of users	C	Rawson
A49	Asociacion de Apicultores de Dolavon y 28 de Julio	Cooperative of beekeepers	Association of users	C	Dolavon
A50	Universidad Nacional de la Patagonia San Juan Bosco	National University	Knowledge production institution	M	Trelew-P Madryn
A51	Universidad Tecnológica Nacional	National Technical University	Knowledge production institution	M	P Madryn
A52	CENPAT	Multidisciplinary research Institute	Knowledge production institution	M	P Madryn
A53	INTA	National Institute of Agricultural Technology	Knowledge production institution	C	Trelew
A54	Museo Egidio Feruglio	Egidio Feruglio Paleontological Museum	Knowledge production institution	C	Trelew
A55	INTI	National Institute of Industrial Technology	Knowledge production institution	C	Trelew-P Madryn
A56	EFPU	Photobiological station of Playa Unión	Knowledge production institution	C	Rawson
A57	Universidad del Chubut	Provincial Univercity	Knowledge production institution	C	Rawson
A58	Aquavida	Center for interpretation of biodiversity from Patagonia	NGO	M	Rawson

Appendix B. List of ecosystem services and attributes

ID	Section	Division	Environment	Ecosystem service
S1	Provisioning	Nutrition	Continental	Food from cultivated crops and reared animals
S2			Continental	Food from wild animals and plants
S3			Continental	Water for drinking
S4			Marine	Food from fishing
S5		Materials	Continental	Fibres and other materials from plants and animals for direct use or processing
S6			Marine	Fibres and other materials from marine organisms for direct use or processing
S7			Continental	Water for non-drinking purposes
S8		Abiotic materials	Continental	Abiotic materials
S9		Energy	Continental	Biomass-based energy sources
S10			Continental	Renewable abiotic energy sources
S11	Regulation & maintenance	Mediation of waste, toxics and other nuisances	Continental	Mediation of waste, toxics and other nuisances by biota and continental ecosystems
S12			Marine	Mediation of waste, toxics and other nuisances by biota and marine ecosystems
S13			Continental	Dilution by atmosphere and freshwater
S14			Marine	Dilution by marine water
S15			Continental	Mediation of smell/noise/visual impacts
S16		Mediation of flows	Continental	Mass stabilization and control of erosion rates
S17			Continental	Transport and storage of sediment by rivers
S18			Marine	Transport and storage of sediment by sea
S19			Continental	Hydrological cycle and water flow maintenance
S20			Continental	Flood and storm protection
S21			Continental	Ventilation and transpiration
S22		Maintenance of physical, chemical, biological conditions	Continental	Lifecycle maintenance, habitat and gene pool protection in continental ecosystems
S23			Marine	Lifecycle maintenance, habitat and gene pool protection in marine ecosystem
S24			Continental	Pest and disease control in continental ecosystems
S25			Marine	Pest and disease control in marine ecosystem
S26			Continental	Soil formation and composition
S27			Continental	Chemical condition of freshwaters
S28			Marine	Chemical condition of salt waters

S29			Continental	Atmospheric composition and climate regulation
S30	Cultural	Physical and intellectual interactions with ecosystems and land-/seascapes	Continental	Physical and experiential interactions with continental environment
S31			Continental	Intellectual and representative interactions with continental environment
S32			Marine	Physical and experiential interactions with marine environment
S33			Marine	Intellectual and representative interactions with marine environment
S34		Spiritual, symbolic and other interactions with ecosystems and land-/seascapes	Continental	Spiritual, symbolic and other interactions with continental ecosystems
S35			Marine	Spiritual, symbolic and other interactions with marine ecosystems

Appendix C. Interview survey

(1) In which Ecosystem Services (ES) have your organization/institution/governmental agency input regarding (a) its use, (b) the regulation of its use, (c) availability management?

(2) What actions have your organization/institution/governmental agency performed to maintain current levels of provision of each ES during the last year?
   (a) Changes in the way or magnitude of using the ES
   (b) Development of rules for its use
   (c) Establishment of policy
   (d) Negotiation with authority

(3) Regarding ES issues, with which actors from the list is your organization/institution/governmental agency related by (a) formal or informal contacts, (b) information exchange, (c) hierarchy or operative rules or (d) common projects?

(4) Within these actors, which ES issues is the relation about?
   (a) Use
   (b) Regulation of use
   (c) Availability or provision levels
   (d) Management policy

(5) The relations with which actors have originated actions regarding ES? Which kind of actions?
   (a) Changes in the way or magnitude of using the ES
   (b) Development of rules for its use
   (c) Establishment of policy

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