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Social diversity for ecosystem management in La Palma Biosphere Reserve, Canary Islands

Perspectives, knowledge and management practices among local stewards in the near-shore marine ecosystem

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Complexity draws attention to the fact that local and traditional knowledge and management systems should be seen as adaptive responses in a place-based context and a rich source of lessons for social–ecological adaptations.

(Berkes et al. 2003b)

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ABSTRACT

Adaptive approaches to ecosystem management emphasize that ecosystems need to be treated as complex social-ecological systems. Furthermore, both ecological and social diversity need to be enhanced to improve the adaptability of such systems to surprises.

Social diversity is approached here by studying the diversity of plausible contributions of local stewards groups to ecosystem management, i.e. perspectives of the ecosystem, ecological knowledge and management practices. These variables are explored by means of 28 interviews to representatives of the 8 local steward groups of the near-shore marine ecosystem of La Palma Biosphere Reserve. The flow diagramming technique is used to elicit mental models about ecosystem.

Results show that local stewards of the studied system provide social diversity. Their contribution differs among local steward groups, being acknowledgeable for official managers, conservationists and professional fishers. However, key carriers of diversity are found in all groups.

Local stewards share a mental model in terms of consensually acknowledging that the near-shore marine ecosystem is degraded and what are the main drivers that lead to this situation. However, they have not been able to respond to them in the current governance system.

Different kinds of knowledge, including experiential and scientific, are gathered, combined, and spread through formal and informal social networks. These networks can provide channels to combine the social diversity in place for the sake of ecosystem management. The Biosphere Reserve Consortium has a key role in facilitating these networks with the potential to become a platform for learning.

The findings draw attention to the need of enhancing formal and informal social networks to gather the diversity provided by local stewards, avoiding the risk of this leading to homogenisation of mental models and knowledge.

Key words: adaptive co-management, local stewards, La Palma, biosphere reserve, social diversity, local ecological knowledge, local management practices, social networks, mental models.

RESUMEN

Un enfoque adaptativo a la gestión de ecosistemas enfatiza la necesidad de entender los ecosistemas como sistemas social-ecológicos complejos. Así, la diversidad ecológica y social debe ser potenciada para mejorar la adaptabilidad de estos sistemas a posibles sorpresas.

La diversidad social se aborda aquí estudiando las posibles contribuciones de los custodios locales a la gestión ambiental, que pueden ser perspectivas respeto al ecosistema, conocimiento ecológico y prácticas de gestión. Estas variables son exploradas por medio de 28 entrevistas a 8 grupos de custodia locales del sistema marino cercano de La Reserva Mundial de la Biosfera de La Palma. La técnica de diagrama de flujo se usa para extraer modelos mentales del ecosistema.

Los resultados muestran que los custodios locales del sistema estudiado proveen diversidad social. Sus contribuciones difieren entre los distintos grupos locales de custodia, siendo especialmente remarcables las de los gestores oficiales, grupos ecologistas y pescadores profesionales. Sin embargo, en todos los grupos se pueden encontrar individuos clave respeto a su aporte de diversidad.

Los custodios locales comparten un modelo mental puesto que reconocen de forma consensuada que el sistema marino cercano está degradado y cuáles son las principales causas que contribuyen a esta situación. Sin embargo, no han sido capaces de responder a estas amenazas en el actual sistema de gobernanza.

Distintos tipos de conocimiento, incluyendo experiencial y científico, se juntan, combinan y distribuyen a través de redes sociales formales e informales. Estas redes proveen canales para combinar la diversidad social para la gestión del ecosistema. El Consorcio de la Reserva de la Biosfera tiene un rol clave al facilitar estas redes con potencial para convertirse en una plataforma de aprendizaje.

Los hallazgos recalcan la necesidad de potencial las redes sociales formales e informales para reunir la diversidad provista por los custodios locales, evitando el riesgo que esto lleve a una homogeneización de los modelos mentales y del conocimiento.

Palabras clave: cogestión adaptativa, custodios locales, La Palma, reserva de la biosfera, diversidad social, conocimiento ecológico local, prácticas de gestión locales, redes sociales, modelos mentales.

INTRODUCTION

Resilience thinking approaches the study of the systems we live in as coupled social-ecological systems (Berkes and Folke 1998, Berkes et al. 2003a). This means that ecosystems cannot be understood apart from the societies and their institutions. Interactions and feedbacks between humans and environment also need to be taken into account.

Social-ecological systems are defined as complex adaptive systems. In such systems, time and space-constrained linear relations and stable conditions are alternated with periods of gradual and abrupt change (Boyd and Folke 2012). The capacity of the systems to deal with this complexity, uncertainty and change is defined as adaptive capacity or adaptability.

Complex problems can hardly be solved with uniform solutions. Universalization of best practices and focus on efficiency has eroded ecological and social diversity by impoverishing the set of sources of novelty for renewal (Folke et al. 2009). Adaptability to the dynamics of complex systems requires acknowledging and making use of sources of social and ecological diversity (Folke et al. 2005).

Diversity is important at all scales. Ecological diversity is addressed from genes and species to landscapes (Levin 1998, Norberg et al. 2008). Social diversity is found from the local to the international level, and refers to the range of experiences, knowledge systems, and institutional responses to ecosystem change (Norberg et al. 2008). Diversity of experiences and ideas provide alternative strategies and can be a source of innovation in the face of new problems (Olsson et al. 2004a).

This thesis chooses to study social diversity for ecosystem management in a local setting. Local stewards, defined here as local actors who manage the ecosystem and their services on the ground (Schultz et al. 2007), are considered as potential local holders of social diversity, providing a range of perspectives, knowledge and management practices. A mental model approach to cognition (Jones et al. 2011) is followed to unravel knowledge and attitudes towards ecosystem management.

The focal ecosystem is the near-shore marine ecosystem of La Palma, i.e. the shallow waters around the island, and the biological communities they embed, down to 50 meters depth. The social system is formed by the local stewards linked to this ecosystem. By choosing a local small system, a rather detailed picture of the diversity of local understanding and management, as well as the particular networks in place, is sought.

While lots of attention has been put into biodiversity in ecosystem management, social and economic diversity in the context of ecosystem management is less well understood (Biggs et al. 2012). Only a few studies have approached social diversity for ecosystem management in place-based case studies (for example, Becker and Ostrom 1995). Studies dealing with individual contributions to social diversity for the management of a local ecosystem have not been found in the literature.

In line with the resilience approach to ecosystem management, it is hypothesized that 1) local stewards provide a variety of mental models, ecological knowledge and management practices, and that 2) this diversity could provide adaptive capacity to the management of the marine ecosystem if well channelled through social networks. These hypotheses are explored by the research questions that guide the thesis (see Box 1).

Box 1. Research questions

General
Do local stewards in the near-shore marine ecosystem of La Palma provide diversity of perspectives towards ecosystem, ecological knowledge and management practices for adaptive co-management?

Operationalized
1. What is the diversity of perspectives, ecological knowledge and management practices offered by local stewards?
2. How is this diversity connected through social networks?

In the next section, the most relevant theory and concepts are presented. This is followed by a description of the social-ecological system studied. The methods used to elicit and analyse local stewards' diversity of cognition and behaviour towards ecosystem are described next. The results and discussion sections present the picture of the varied perspectives, ecological knowledge and management practices, and the contribution of local steward groups and individuals to this diversity. This is followed by the analysis of two social networks in place that provide the basis for the combination of this diversity and the potential for learning. The study ends with the lessons that can be concluded from this study.

THEORETICAL FRAMEWORK

Failures in many conventional scientific and technical approaches to resource and ecosystem management have sparked an interest to find new site-specific approaches to each particular social-ecological system so that management becomes more responsive, adaptive and resilient (Ludwig et al. 1993, Folke et al. 1998).

Local stewards and perspectives of the ecosystem

Local stewards are local actors who manage the ecosystem or its services and have local ecological knowledge (LEK) developed through their activities in ecosystems (Schultz et al. 2007). They can do so as representatives of governmental agencies, companies, and associations or as individuals.

Mental models are personal internal representations which can be elicited in order to better understand the way people think, communicate about and interact with the world around them (Jones et al. 2011, Lynam et al. 2012). They are used in this research to reveal knowledge of and attitudes towards ecosystem management (Zhang et al. 2013). Indeed, “the cognitive dimensions of social-ecological systems are a key, and yet little discussed, component of these complex systems” (Lynam et al. 2012).

Local ecological knowledge

According to the conceptual framework for analysing linked social-ecological systems (see Fig. 1), ecological knowledge and understanding provide the linkage between ecosystems and management practices, i.e. between the ecological and social parts of the system. This link is of critical importance for a sustainable use of the resources and the ecosystems (Berkes and Folke 2002). This thesis seeks to deepen the understanding of ecosystem management on the local social-ecological system yet acknowledging that it is embedded in larger systems that affect it.

Fig. 1. Conceptual framework for the analysis of social-ecological systems (Berkes et al. 2003a, after Berkes and Folke 1998)

Local ecological knowledge is defined as "knowledge held by a specific group of people about their local ecosystems" (Olsson and Folke 2001). This a priori experience-based knowledge (Fazey et al. 2006, Gray et al. 2012) would be distinguished from scientific knowledge for being site-specific and contextualized knowledge generated through local observations and experiments (Gadgil et al. 2003). However, ecological knowledge of stakeholders can be a mix of experiential and scientific knowledge to different degrees (Olsson and Folke 2001, Tengö and Belfrage 2004, Brook and McLachlan 2008, Gray et al. 2012).

In the field of aquatic ecosystems, fishers' knowledge has been proven to be of great value for fisheries' science and management (Haggan et al. 2007). Research has mainly focused on the fisher's ecological knowledge of the targeted species (Olsson and Folke 2001, Davis et al. 2004, Crona and Bodin 2006, Garavito et al. submitted). For a review on local and traditional knowledge and practices in marine environment see Thornton and Maciejeweki (2012).

Previous studies argue that scientific and local (including traditional) knowledge systems can be combined to enhance ecosystems co-management (Moller et al. 2004, Crona 2006). LEK is presented as a source of novelty and innovation (Seixas and Berkes 2003) and knowledge diversity is suggested to enhance capacity to deal with change (McLain and Lee 1996, Johannes 1998, Ludwig et al. 2001, Folke et al. 2005, Gray et al. 2012).

Management practices

Local ecological knowledge and understanding are the basis for socially and culturally evolved management practices (Folke et al. 1998). Official management, on the other hand, is usually based on scientific data and knowledge of official managers, it is focused on collecting quantitative synchronic and short-term data, and generally pursues efficiency in the short term by blocking disturbances (Folke et al. 1998). However, some practices to build resilience may also be implemented by official managers such as seasonal closures of harvest or protection of species and habitats (Berkes and Folke 2002).

Some studies provide insights about management practices in western countries. In the river basin of Kristianstads Vattenrike (Sweden), contribution to ecosystem management by local steward groups were found to be: on-site management, monitoring and response, local ecological knowledge, generating support for ecosystem management, and specialized networks (Schultz et al. 2007). Olsson and Folke (2001) showed that local fishers of Lake Racken Watershed carried out management practices and held LEK about crayfish population from the individual to the watershed. A comparison between management practices of farmers in Sweden and Tanzania (Tengö and Belfrage 2004) showed in both cases practices that increased the farms' capacity to deal with recurrent disturbances such as pests and climate variability. Those practices included building insurance capital to buffer disturbances, mechanisms for dealing with disturbances, practices for dampening the effect of disturbances, and those that sustain ecological processes important for the system to recover after a disturbance.

Social diversity in a local social-ecological system

Diversity in social-ecological systems refers to biodiversity, spatial heterogeneity, livelihood strategies, and institutional diversity (Biggs et al. 2012). A diversity of stakeholders or users groups provides different approaches to the ecosystem, thus it enhances a diversity of knowledge and understanding, and is the basis for learning processes. This improves the capacity of the system to renew and reorganize in response to environmental feedback (Walker et al. 2002, Olsson et al. 2004a).

Social networks have been proven to be of importance in ecosystem management (Wilson 2002, Olsson et al. 2004b, 2004a). In this sense, it is argued here that social diversity can be captured and combined through social networks of knowledge exchange.

“Networks provide access to novel information and influence the way information is being processed” (Crona et al. 2011). For our interest, social networks can provide access to different sources of ecological knowledge (Hahn et al. 2008).This can be particularly determinant in turbulent times, when networks of stakeholders can mobilize knowledge and social memory, enabling the capacity to deal with uncertainty and shape change (Folke et al. 2005). Social memory is define here as “long-term communal understanding of the dynamics of environmental change and the transmission of the pertinent experience” (Berkes et al., 2003:20).

Local knowledge and management practices have mainly been studied for certain local or traditional communities, usually compared to those of scientific sources. However, studies addressing the diversity of management practices and ecological knowledge provided by actors in a local system have not been found in literature, with the exception of a study that compares knowledge provided by fisher groups (Crona and Bodin 2006).

The research on mental models applied to human-environment interactions is incipient. The few known attempts to study diversity of mental models in this context are the studies by Mathevet et al. (2011) and Stone-Jovicich et al. (2011) addressing water use and management. In the Camargue Biosphere Reserve (Mathevet et al. 2011) found that mental models where shared within the core Water Board and differed for the rest of stakeholders according to the degree of involvement with this group. Stone-Jovicich et al. (2011) did no find consensus within or between groups in a river catchment of South Africa.

This thesis combines diversity of mental models, management practices, and local ecological knowledge for ecosystem management among stewards of an ecosystem. This is believed to be of importance to deepen the understanding of the sources of social diversity in a local social-ecological system for adaptive co-management.

CASE STUDY DESCRIPTION

La Palma is the most northern-westerly island of the Canary Islands archipelago (Spain). Its origins are volcanic and it has an area of 708 km^2, being the 3rd smallest island. The archipelago is situated in front of the north-east African coast and has a subtropical climatology (see Fig. 2).

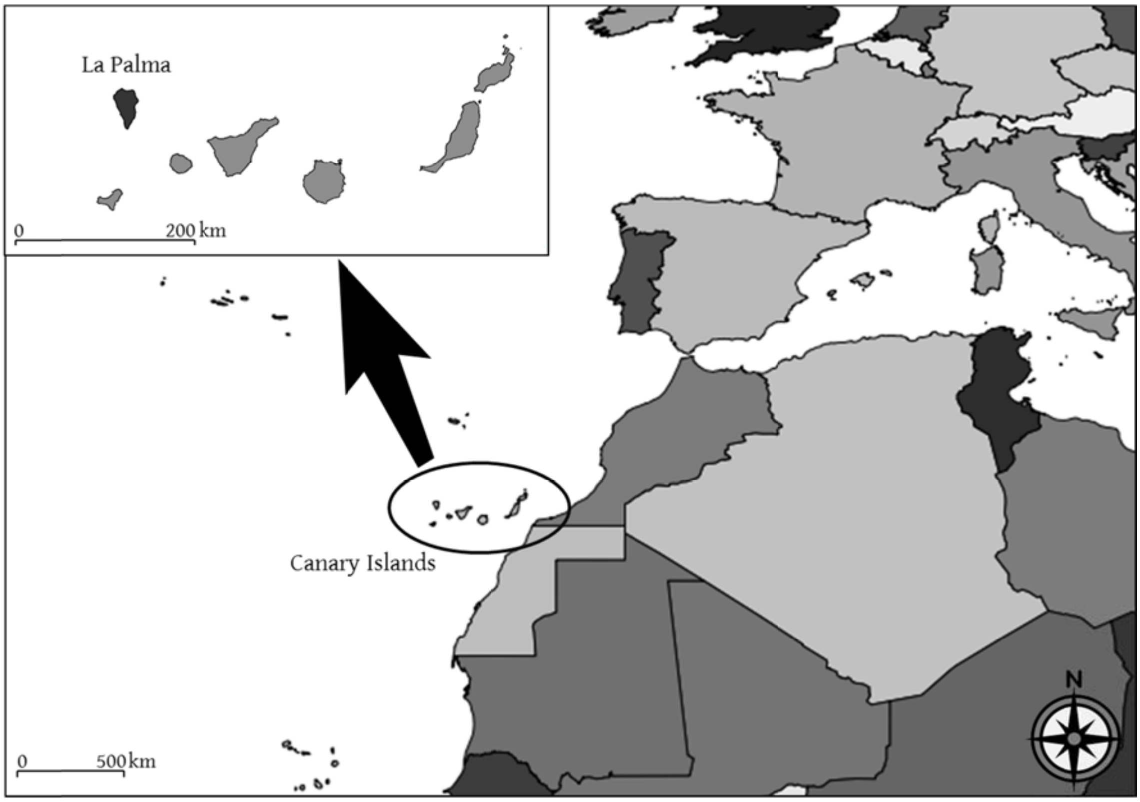

Fig. 2. Location of La Palma in relation to the Canary Islands and the nearest countries. Sources: GISCO - Eurostat (European Commission) ©EuroGeographics, UN-FAO and Turkstat (http://epp.eurostat.ec.europa.eu/portal/page/portal/gisco_Geographical_information_maps/geodata/) and Spatial Data Infrastructure of Canary Islands (http://www.idecan.grafcan.es/idecan).

According to the Canary Institute of Statistics (Instituto Canario de Estadística 2013), La Palma has a population of 85.468 inhabitants (1st January 2012). In 2012, 1,2% of tourists travelling by plane to the Canary Islands chose La Palma. On average, 125.000 tourists visit the island every year. In 2010, 4,9% of its inhabitants were employed in activities related to direct use of natural resources, including farming, forestry and fishing, producing 2,7% of the gross added value.

Since 2002 the whole island of La Palma is a biosphere reserve (BR) designated by UNESCO's Man and Biosphere Program after two extensions of the 511-ha initial area in 1983 to protect the Macaronesian laurisilva forest. At present the BR covers 80.702 ha, of which 9.870 ha are marine and divided in two areas in the North and South-West (see Fig. 3). This southern area embeds the Marine Reserve of La Palma, a marine protected area designated by the Spanish government with the goal to protect and enhance the fisheries' resources.

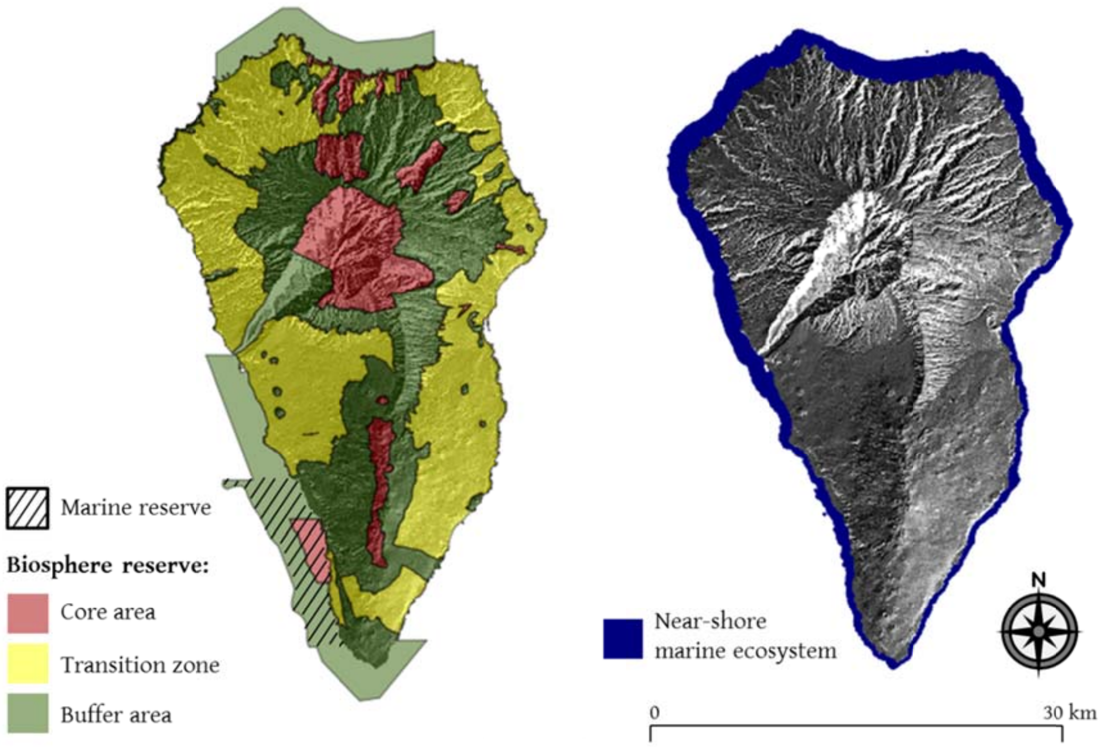

Fig. 3. Zonation of the BR and Marine Reserve (left) and the near-shore marine ecosystem of La Palma (right). Sources: Mundial Biosphere Reserve of La Palma and University of La Laguna (http://www.lapalmabiosfera.es), Spatial Data Infrastructure of Canary Islands (http://www.idecan.grafcan.es/idecan)

The biosphere reserve centre, defined as a place-based body that coordinates the activities related to the BR functions (Stoll-Kleemann and Welp 2008, Schultz and Lundholm 2010), is the La Palma World Biosphere Reserve Insular Consortium, hereafter referred to as Biosphere Reserve Consortium (BRC).

From 2008 to 2011, the BRC developed the Marcopalma project. The aim was to gather the available knowledge of the marine environment, including its main communities, as well as to characterize the human activities taking place. When lacking, the project generated ecological knowledge by means of scientific monitoring and observation (Martín et al. 2009, Martín et al. 2011).

The short age in geological terms and the volcanic origins of the island have resulted in a very steep relief and thus a thin insular platform. The sub littoral area down to 50-60 meters deep is where most of the primary benthonic production takes place, hence harbouring the highest marine biodiversity and the most complex trophic linkages of the marine system (Sangil et al. 2009).

Shifts of marine ecosystems into alternative degraded states have been described for many coastal areas (Nyström et al. 2012). In many shallow waters of La Palma, seaweed stands have turned into urchin barrens (Brito et al. 2004, Tuya et al. 2004). Overfishing of key predators has provoked top-down changes leading to sea-urchin dominated landscapes. This has resulted in a reduction of seaweed coverage and a decrease of fish abundance. However, the implementation of fishing restrictions in the marine reserve has proven to be beneficial for a rapid restoration of seaweed stands and subsequent community-wide effects (Sangil et al. 2012).

The BR concept is increasingly embraced by scientists, planners, policy makers and local communities as an umbrella for bringing their knowledge, research and experience to ecosystem management (UNESCO-MAB 2008). Previous research (Schultz et al. 2011) indicated that even if La Palma BR was managed by governmental actors, there was certain interaction with different stakeholders. In this context, La Palma BR was selected from a survey of 148 biosphere reserves to disentangle how diversity looks like in a setting with limited though increasing participation.

The local stewards of the near-shore marine ecosystem of La Palma (see Fig. 4) were found to configure a broad range of actors divided into 8 local steward groups, hereafter LSG: official managers (O), guards (G), conservationist non-governmental organizations (C), land-based economic activities (L), sea-based economic activities (except professional fishing) (S), professional fishers (PF), sport fishers (SF) and stewards involved in recreational activities (except sport fishers) (R). The detailed list can be found in Appendix 1.

Fig. 4. Local stewards of the near-shore marine ecosystem of La Palma. From upper left to down right: boats of cetaceans sightseeing companies, a sport fisher, professional fishers, and surfers.

As opposed to the common perspective on local stewards (Schultz et al. 2007, Birge and Fred 2011), a novel approach of this research is that local official managers and guards, i.e. stewards working in governmental organizations, are included as local steward groups. As a distinctive feature to the other LSG, they are local civil servants that pursue ecosystem management as a main goal of their work activities. Adding them in this research is intended to achieve a more complete picture of the social diversity in the system.

METHODS

This study uses social science methods and qualitative data as a way to approach the complexity of social-ecological systems and to understand their behaviour while aiming to increase knowledge to better manage them (Berkes et al. 2003b).

As shown in Fig. 5, different methods were used through the three phases of the research –research design, field work and data analysis–.

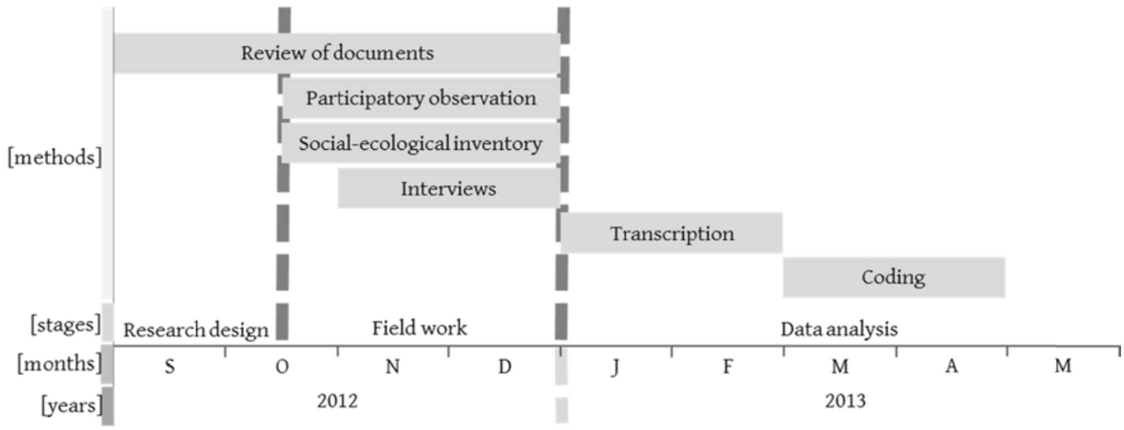

Fig. 5. Overview of the research stages and methods used.

Sample selection

As a way to identify local stewards, a social-ecological inventory (Schultz et al. 2007) was conducted. Participatory observation and informal conversations (Patton 2002) with the staff of the BRC informed the choice of the focal ecosystem. They were also asked to identify individuals or organizations managing the near-shore marine ecosystem and its services. In turn, these actors were asked to also identify other stewards using the snowball sample method (Biernacki and Waldorf 1981).

Review of relevant official documents, such as project reports, meeting notes and websites was done in preparation for and during the field work to gather information about the environment, management practices and actors involved. They were also used as sources of information about other plausible stewards outside the network of the BRC. Also, other informants were identified by the author by means of observation of the system and asking sources not linked to the BRC. In total, 28 local stewards were identified and interviewed.

An effort was made to include a diversity of informants. The criteria for the selection of targeted stewards took into account diversity of geographic areas, organizations –including non-organized stewards– and age. In terms of geographical distribution, informants operated from the three harbours in the island –Santa Cruz de La Palma, Tazacorte and Puertoespíndola–, beaches, and from inland, depending on their activities.

The targeted interviewees were representatives of local governmental agencies as well as non-official steward groups and individuals, including representatives of ecosystem users, managers of activities connected to the sea, and non-governmental organizations.

Data collection

The interviews were semi-structured, using a mix of interview guide and informal conversation. Because the focal group of interviewees was very varied and with different backgrounds, the approach was chosen to allow flexibility to particular individuals and circumstances (Patton 2002), adapting the wording to the vocabulary of the interviewee. Moreover, the approach allowed the emergence of issues not captured by the interview guide that could be of interest to answer the research questions.

The questions were based on the conceptual framework for analysing linked social-ecological systems by Berkes and Folke (2002), with a focus on ecosystem change, local ecological knowledge and local management practices. They were divided into three sections, the first asking about the most valued aspects of the landscape in general and the marine system in particular, as well as motivations for daily activities related to the marine ecosystem. The second section asked about activities in the marine system and sources of information to properly develop such practices. In the last section, the interviewees were asked to define the main features of the marine ecosystem. There were also two questions regarding changes in the ecosystem witnessed by the interviewees and those that they had not witnessed, but knew about from other sources of information. The complete interview guide is found in Appendix 2.

The flow diagramming technique (Pretty et al. 1995) was used to elicit mental models of interviewees, thus capturing their cognition (Jones et al. 2011) and practice. They were asked about the main threats to the marine environment of La Palma, as well as the main solutions to them, with follow-up questions to deepen the understanding of the interviewee. The result showed the interviewees' ecological knowledge, perception of ecological change and its driving forces, and suggested management practices to deal with change.

Data analysis

The interviews were recorded and transcribed using InqScribe software and the analysis included coding with Atlas.ti software.

Dale et al. (2000) defined five principles important for ecosystem management (see Table 1) that have proven useful to analyse and compare ecological knowledge (Olsson and Folke 2001, Crona 2006). These categories were used to code and analyse the flow diagrams.

Table 1. Principles for ecosystem management (Dale et al. 2000)

Time	Ecological processes function at many time scales, some long, some short; and ecosystems change through time
Species	Particular species and networks of interacting species have key, broad-scale ecosystem-level effects
Place	Local climatic, hydrologic, edaphic, and geomorphologic factors as well as biotic interactions strongly affect ecological processes and the abundance and distribution of species at any one place
Disturbance	The type, intensity, and duration of disturbance shape the characteristics of populations, communities, and ecosystems
Landscape	The size, shape, and spatial relationships of landcover types influence the dynamics of populations, communities, and ecosystems

Management practices to code the interviews were inspired by those suggested by Berkes and Folke (2002) and Tengö and Belfrage (2004) (see Table 2). Only individual practices were studied, acknowledging that local practices can also be embedded in local or larger institutions (Olsson and Folke 2001).

Table 2. Local and traditional resource-use practices valuable in resources management for dealing with uncertainty and change. The second and third columns refer to practices defined by Berkes and Folke (2002), and Tengö and Belfrage (2004) based on the model of adaptive renewal (Holling 1986, Gunderson and Holling 2002). The fourth column shows the categories of practices chosen for coding the interviews.

Phases of the adaptive renewal cycle	Management practices proposed by Berkes and Folke (2002)	Management practices proposed by Tengö and Belfrage (2004 after Berkes and Folke 2002)	Management practices used to code the interviews
Exploitation and conservation phases (foreloop)	Qualitative monitoring (diachronic information)	Monitor and circumscribe uncertainty by use of qualitative measures and indicators	Qualitative monitoring
			Quantitative monitoring
	Management using qualitative data	Practices that build insurance against disturbances	Practices that build insurance against disturbances
Release and reorganization phases (backloop)	Building resilience: practices that mimic the disturbance at lower scales of the panarchy and those that nurture sources of renewal	Practices that enhance conditions for ecological functioning and recovery: dampening the effect of disturbances and sustaining ecological processes important during the backloop	Practices that enhance conditions for ecological functioning and recovery
	Providing long time-series of local observation and institutional memory for understanding ecosystem change		Practices that provide long-time series of local observation and social memory

Special attention was given to identify incongruences among the contribution of each steward in terms of contradictory perspectives, ecological knowledge or management practices. Based on these variables, the diversity provided by each informant and group was assessed. This was done by a new framework aiming to capture quantity and quality of these variables by using the aspects: quantity, variety and originality, defined in Table 3.

Table 3. Aspects of diversity analysed

Quantity	Number of elements: threats, solutions, statements of ecological knowledge or management practices mentioned.
Variety	Number of categories, i.e. groups of elements, of threats, solutions, ecological knowledge and management practices (based on Stirling 2007).
Originality	Original elements: threats, solutions, statements of ecological knowledge or management practices mentioned by the least number of stewards.

According to Stirling (2007), diversity in a system is a combination of three properties: variety, balance and disparity. Social diversity has been analysed in terms of diversity provided by local stewards groups and individuals rather than assessing how diverse the social system is. For this reason, the framework proposed by Stirling (2007) was used as guidance but modified in depth to adjust it to the aims of the thesis.

The social network approach (Bodin and Prell 2011) was used to identify one formal and one informal network of communication within the local system and connections to outer sources of knowledge. The nodes were actors providing ecological knowledge to the network, i.e. organizations, commissions or actor groups. The links were defined as one-way flow of ecological knowledge.

These two networks of knowledge sharing were mapped from interviews and follow-up questions to the BRC staff. Other sources were project reports for the formal network and interviews to a non-governmental organization (NGO) representative for the informal one.

RESULTS

This section starts by presenting the local stewards' perspectives towards the ecosystem, broken down into threats and solutions. Then, their contributions in terms of ecological knowledge and management practices are presented, followed by an overview of the diversity of the previously described variables: perspectives, ecological knowledge and management practices. The section ends with a representation of knowledge sharing networks in place.

Perspectives of the ecosystem

The flow diagrams showed the mental models of the interviewees when approaching the near-shore marine ecosystem of La Palma. Two diagrams were drafted from each interview, one showing the threats to the system and another showing the suggested solutions. Flow diagrams from two different interviewees are shown in Fig. 6 and a complete list of threats and solutions mentioned is shown in Appendix 2.

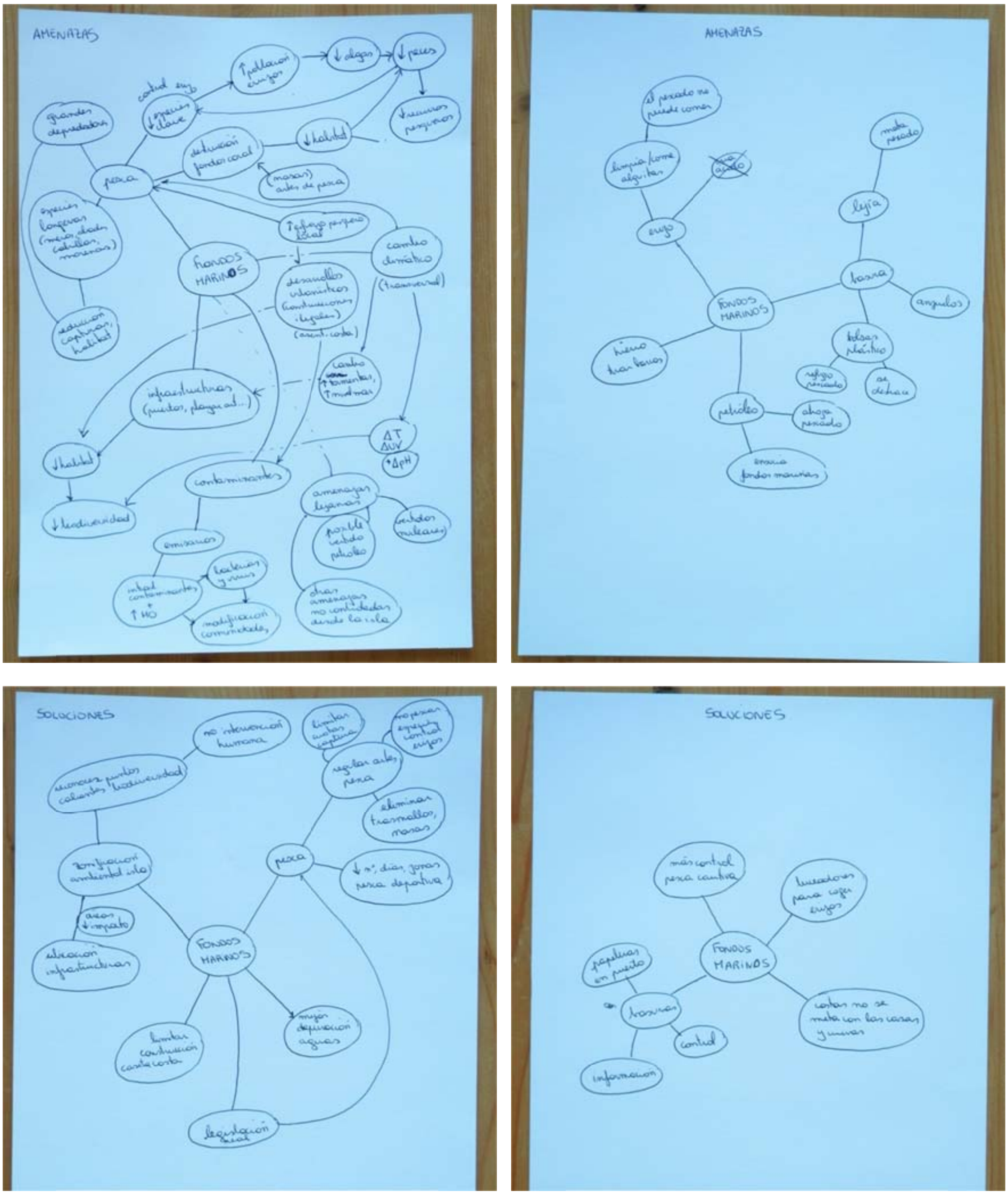

Fig. 6. Flow diagrams elicited from interviews. The central circle refers to the marine ecosystem (*fondos marinos*), linked to the different threats (upper diagrams) and solutions (lower diagrams) mentioned by two interviewees. They show different levels of understanding of the threats and solutions, including their complexity and linkages.

a) What were the identified threats to the near-shore marine ecosystem?

The number of threats identified, divided into 9 main categories is shown in Fig. 7. In *overfishing*, outbreaks of sea urchins, too harmful fishing gears, and non-compliance were the most recurrently cited. *Pollution* included solid, liquid and radioactive waste from different sources. *Oil spills* are represented separately, as this was a repeatedly mentioned threat from navigation or exploratory drilling. *Aquaculture* was identified as a source of different perturbations such as invasive species and several impacts to the wild fauna. Impacts from *banana crops* included phytosanitaries, fertilizers and plastic from greenhouses. *Climate change* and impacts derived from *transport* were less mentioned. Invasive species, change of the Law of Coasts, visual impact by greenhouses and mass tourism were mentioned by one or two interviewees and are grouped in the *others* category.

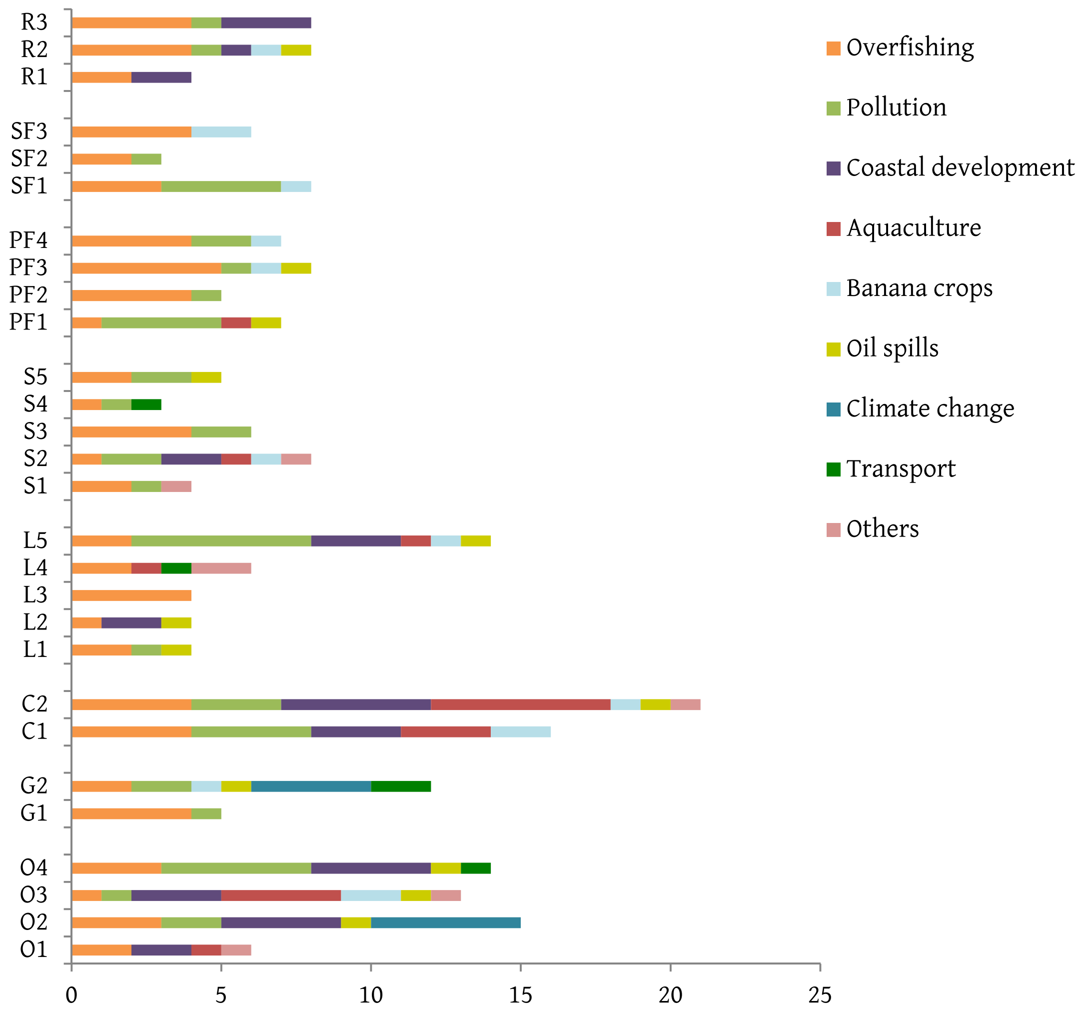

Fig. 7. Threats to the near-shore marine ecosystem. The x-axis refers to the number of threats faced by the marine ecosystem as mentioned by each interviewee. The informants, grouped in LSG, are distributed in the y-axis. O: official managers, G: guards, C: conservationists, L: land-based economic activities, S: sea-based economic activities (except professional fishers), PF: professional fishers, SF: sport fishers, R: recreation (except sport fishers).

Only one category of threats was consensually identified by all groups: *overfishing*. All professional fishers also mentioned *pollution*. Official managers pointed out *coastal development* and most of them also mentioned *pollution* and *oil spills.* Local stewards doing recreational activities mentioned *coastal development.* Conservationists showed a high degree of consensus on the categories of threats mentioned.

b) What solutions to overfishing were proposed?

Informants gave concrete solutions to deal with each mentioned threat and also general solutions to improve the ecosystem status. In Fig. 8, solutions to deal with overfishing given by each informant are shown. The solutions are grouped into 6 categories, and include the concrete and the general ones.

*Increase knowledge and raise awarenes*s is a broad category embedding environmental education, training and communication campaigns. *Management* ranged from general seascape planning to quotas, closed seasons and marine reserves. *Legislation* and *control* to avoid non-compliance were the most mentioned solutions. As opposed to control, *compliance* refers to interviewees mentioning that compliance was necessary regardless of any coercive action to ensure it. The *others* category embeds isolated answers such as more engagement from politicians and research.

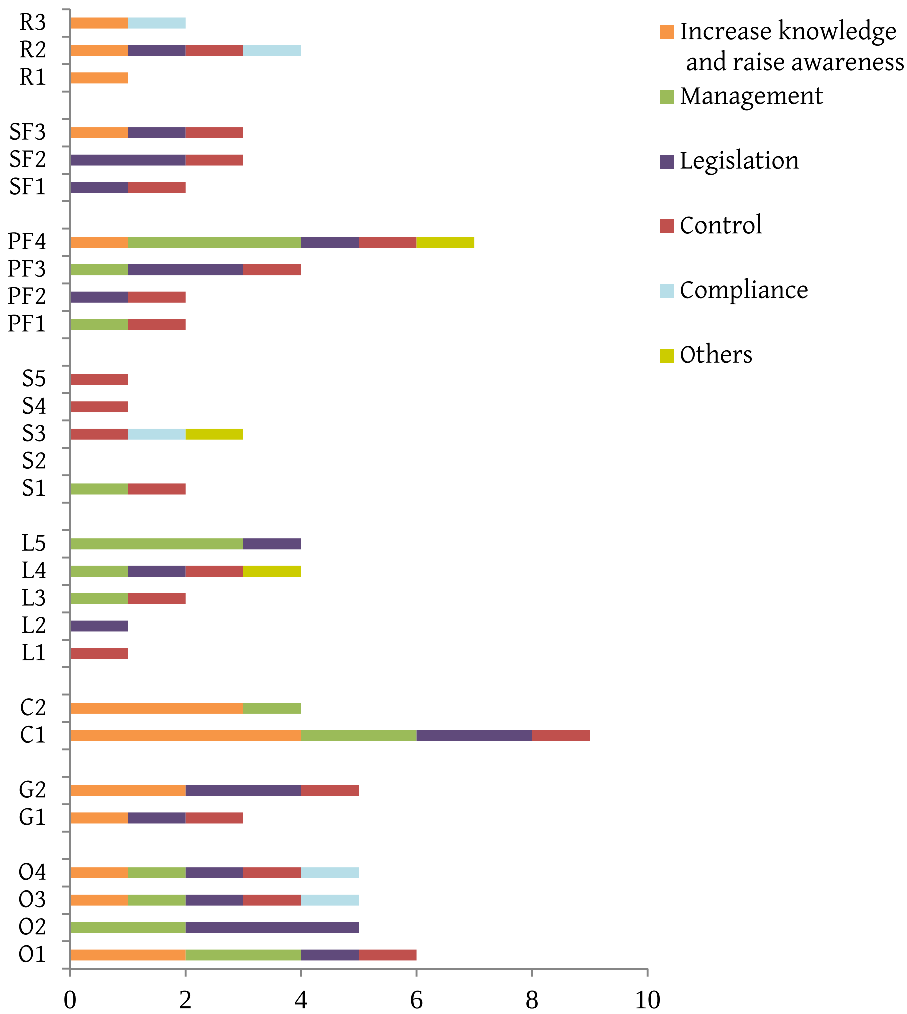

Fig. 8. Solutions to deal with overfishing. The x-axis refers to the number of solutions mentioned by each interviewee. The informants, grouped in LSG, are distributed in the y-axis**.** O: official managers, G: guards, C: conservationists, L: land-based economic activities, S: sea-based economic activities (except professional fishers), PF: professional fishers, SF: sport fishers, R: recreation (except sport fishers).

In general, the LSG did not show homogeneity in the kind of solutions mentioned. However, some general patterns can be described. The conservationists, for instance, tended to favour the solutions to *increase knowledge and raise awareness* and they also mentioned *management*. All official managers mentioned *management* and *legislation*. The answers of the representative of the BRC showed a more broad and interrelated approach compared to the other interviewees. He described an accurate plan to deal with a big range of threats of the marine ecosystem. All sport fishers believed that more *legislation* and *control* was needed. Professional fishers also shared the concern for *control*, but showed more diversity of approaches to overfishing, most of them also aimed for more *management* and *legislation*. All the local stewards doing recreation activities mentioned *increase knowledge and raise awareness*. The two guards mentioned solutions to *increase knowledge and raise awareness*, and more *legislation* and *control*.

Ecological knowledge for ecosystem management

The body of local ecological knowledge of the near-shore marine ecosystem held by informants is described in Appendix 4. The general loss of fish abundance, loss of algae coverage and sea urchin outbreaks were known by local steward groups. They were also aware of the recovery of marine ecosystems in the Marine Reserve of La Palma as a result of fishing restrictions. They shared an understanding of what are the conditions that allow a highest biodiversity, namely, rocky grounds with algae coverage, which are placed in the thin insular underwater platform of the island.

Local stewards also acknowledged the main disturbances affecting the biodiversity, mainly related with fishing activity. The increase of the fishing pressure with new technology and new gears, pond nets in particular, was identified as a driving force leading to reduction of fish biomass, including certain key species that control sea urchin populations. In turn, sea urchin outbreaks were known to be the cause of urchin barrens without algae coverage and the communities supported by these algae. Other disturbances to the marine ecosystem were acknowledged such as liquid and solid pollution and the impacts of alien species, e.g. the European seabass and the croacker, when interacting with native species.

Fig. 9 shows the knowledge elicited by each local steward, divided into the five principles for ecosystem management. The more knowledgeable individuals appeared to be the members of the biosphere reserve interviewed, the representatives of the conservationist NGOs and two professional fishers (PF3 and PF4). One of the professional fishers (PF4) also showed a highly diverse understanding because he showed knowledge under the five categories analysed.

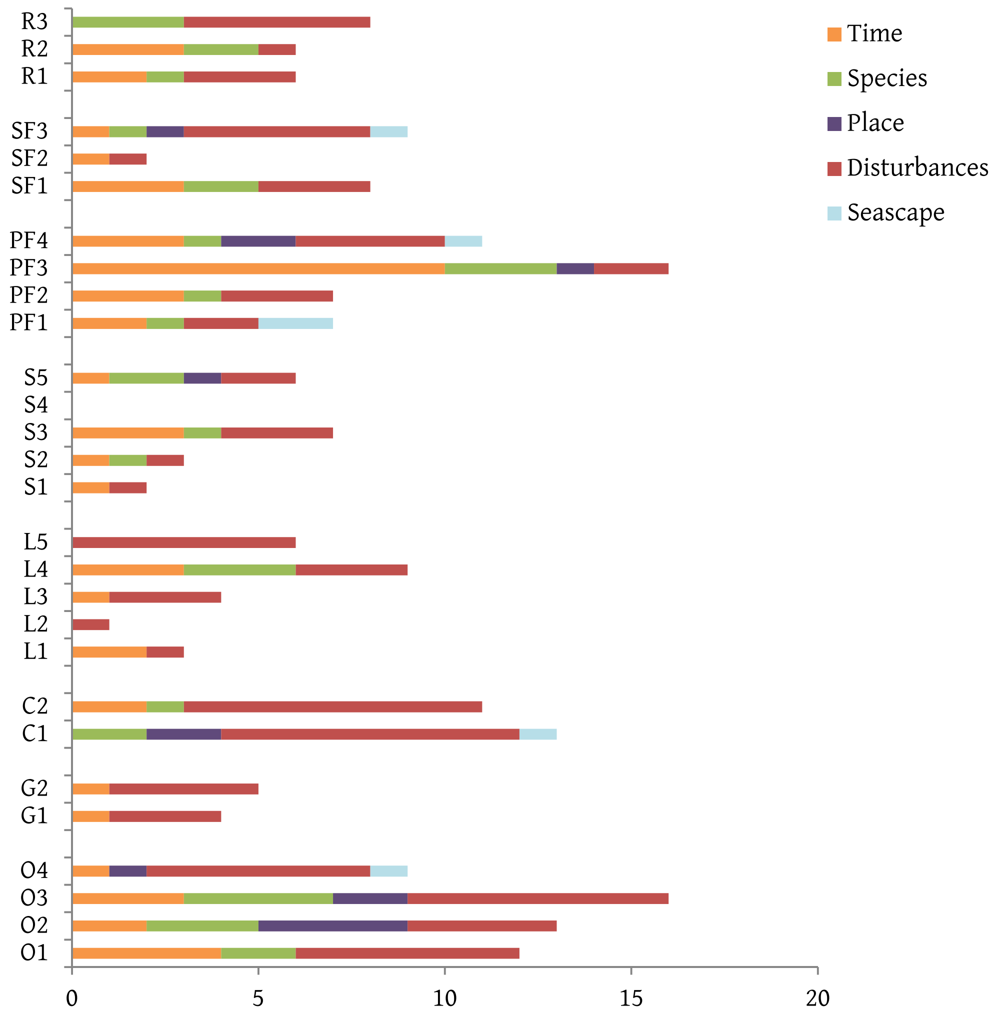

Fig. 9. Knowledge valuable for ecosystem management. Number of statements of ecological knowledge indicated by each steward, grouped into the five principles important for ecosystem management (adapted from Dale et al. 2000). The informants, grouped in LSG, are distributed in the y-axis. O: official managers, G: guards, C: conservationists, L: land-based economic activities, S: sea-based economic activities (except professional fishers), PF: professional fishers, SF: sport fishers, R: recreation (except sport fishers).

Official managers, conservationists, professional fishers and sport fishers were the groups that showed knowledge under the five categories. Knowledge about *time* and *disturbances* was revealed by all groups. Conservationists and recreationists also showed knowledge under the category *species*.

Management practices

Three different kinds of management practices carried out by local stewards were found: qualitative and quantitative monitoring of ecosystem change and practices that build insurance against disturbances (Table 4).

Table 4. Management practices. Management practices mentioned by local stewards during the interviews. The number of local stewards carrying out these practices is shown in brackets. Categories after Berkes and Folke (2002) and Tengö and Belfrage (2004).

Management practices	Concrete practices or focus of monitoring
Qualitative monitoring	Changes of fish abundance or medium size of individual (8) Changes in algae coverage (5) Impact on the ecosystem of human activities (e.g. aquaculture, sanitation plant, enlargement of the harbour) (4) Changes in sea urchins density (3) Changes of periodic climatic events (3) Recovery of the ecosystem in the marine reserve (1) Changes of the coastline shape (1)
Quantitative monitoring	Direct quantitative monitoring of a broad range of indicators (3) Quantitative monitoring of targeted fish (1) Support for quantitative monitoring of targeted fish populations (1)
Practices that build insurance against disturbances	Open blind or lost pond nets (4) Rescue turtles entangled with plastic waste (3) Pick up solid waste when scuba diving (2) Elimination of sea urchins (2)

Fig. 10 shows the management practices carried out by informants. A professional fisher (PF1) and the head of an underwater rescue team (S3) stand out for doing the highest number of practices. If grouped by local steward groups, professional fishers are those who do more practices and more diverse followed by stewards engaged with recreational activities. On the other side, representatives of sea-based economic activities do a smaller number of management activities. The management practices of official managers and guards are usually part of their jobs but they also do some management on a voluntary basis.

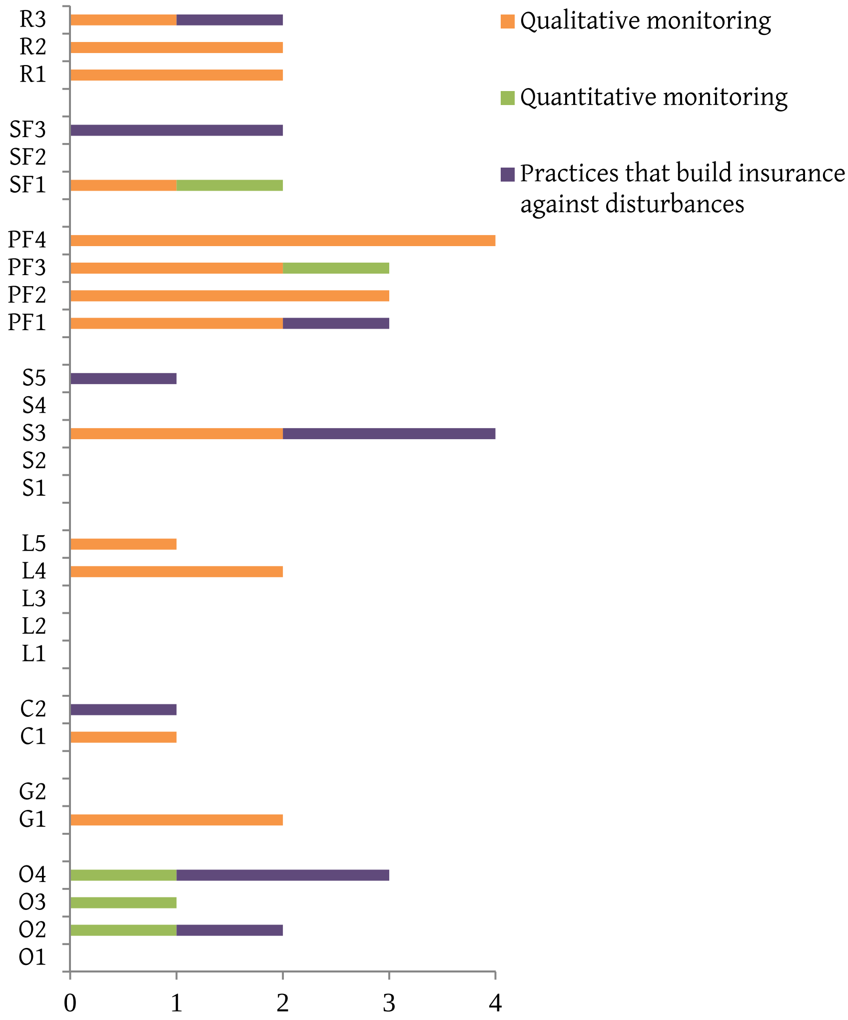

Fig. 10. Management practices valuable in ecosystem management. Practices for dealing with uncertainty and change carried out by each local steward. Categories after Berkes and Folke (2002) and Tengö and Belfrage (2004). The informants, grouped in LSG, are distributed in the y-axis. O: official managers, G: guards, C: conservationists, L: land-based economic activities, S: sea-based economic activities (except professional fishers), PF: professional fishers, SF: sport fishers, R: recreation (except sport fishers).

Practices enhancing conditions for ecological functioning and recovery and examples of stewards providing *long-time series of local observation and social memory*, as suggested by Berkes and Folke (2002) and Tengö and Belfrage (2004), were not found from the interviewees. However, some stewards mentioned old relatives or peers when talking about past changes in the marine ecosystem. Other stewards had witnessed themselves the reduction of fish abundance and the disappearance of certain habitats due to a live-long relationship with the sea.

a) Qualitative monitoring

Local stewards did activities related to the marine ecosystem on a regular basis thus they qualitatively monitored the ecosystem. Many examples of this monitoring activity were found during the interviews but here attention has been put on monitoring of change in the ecosystem. Only interviewees who gave concrete examples or clearly showed that they had witnessed these changes are included in Table 4 and in Fig. 10.

A professional fisher (PF1) talked about the increase of tuna fish as a consequence of reduced pressure of tuna populations in Saharan waters:

> *When they took back the permission [to fish] at the Canary-Saharan Bank, the big boats had to stay in Tenerife. (…)When the fishing boats stop the fish down there it doesn't get to the Canary Islands. This year (…) they did not give them any permission and it has been the best year for tuna*.

A distinct monitoring activity was described by the surfer (R1) interviewed, he noticed change on the shape of the coastline and on the shallow grounds:

> *At the other side of the island I found a wave that did not exist, because I had been there before (…). There was a fire; it rained too much, it dragged soil, stones, rubbles, lots of garbage (…) that entered the sea inside (…). It was filled in one day and in a few months this was flatten, and now there's a perfect wave.*

Many of them acknowledged changes in fish abundance, diversity and individual size. A professional fisher (PF4) explained the decrease of fish abundance in terms of decrease of catches:

> *When I was a child, I was in the fishing world for my father. I saw those tremendous catches, only spending 2 hours, and using a cord or line. And now you spend the whole day, working hard, and come back with 4-5 kilos of fish.*

Changes of periodic climatic events were described by the head of the underwater rescue team (S3):

> *Before there was real summer, you do not know when it is summer now. There was the fair weather of September, the sea was very calm, and now you do not know when it will happen.*

b) Quantitative monitoring

Both the staff of the biosphere reserve and the staff of the marine reserve perform scientific-based quantitative monitoring of the ecosystem. Local stewards are not intentionally collecting data for management purposes but two local stewards were found to do activities that complement the data collection of fish populations by formal management.

The representative of a sport fishers association (SF1) explained that he keeps track of the catches of the members of the association and that this data may be required by government agencies. In his own words:

> *Everything is written here. Then I archive and keep it, sometimes the Regional Government demands reports, [to know] what has been caught and how many kilos, if they want to do any study, or know what kind of fish we catch, which we catch more, or less, or not at all.*

Professional fishing is used by the staff of the marine reserve to support the regular monitoring of fish populations. This support can be adapted to funding availability. The representative of a professional fishers association (PF3) indicated it while emphasizing that the last time he did it on a voluntary basis:

> *[The Marine Reserve staff] selected different points, they did it the last 3-4 years, and I dropped the nets 350 meters during 2 hours, then they took it out and monitored the fish. (…) Inside the Reserve you would throw the nets at 3-4 points and 3-4 more outside, 7 in total. (…) Now with the [economic] crisis they came while I was fishing and did not touch anything, they just*

monitored and then I got the fish back. I did not mind to have them there but I could have refused.

c) Practices that build insurance against disturbances

According to most of the local stewards interviewed, pond nets are a severe disturbance because they are non-selective and work 24 hours a day. According to the legislation, one fisher can own up to 15 pond nets, and they need to be linked to a buoy showing the owner identification and making them visible[1]. Unidentified pond nets are called blind pond nets and are used to hide the ownership, enabling the fisher to drop more than the maximum number permitted or place them in unauthorized places. These pond nets are difficult to get back and face a high risk to become lost. If this happens, the gear keeps fishing during years until the metallic net is rod and breaks. Some interviewees reacted to that threat by opening the blind or lost pond nets and liberating the fish kept in there. A sport spear gun fisher (SF3) stated:

> *I have found blind pond nets with hundreds of fish inside dying and attracting other fish (…) I go down with a knife, cut the net, open the pond net, break it and let it there opened so the fish can go in and out, and a problem from the sea is eliminated.*

Other practices to deal with particular threats are spontaneously carried out by local stewards. Examples are taking care of turtles trapped into plastic waste, eliminating sea urchins to reduce their density and collecting solid waste from the grounds. For instance, the fire fighters' underwater rescue team organizes cleaning of the grounds as a scuba diving training exercise.

Diversity

The diversity provided by each local steward is summarized in Table 5 based on their statements of threats, solutions, ecological knowledge, and management practices. For

[1] Spanish legislation on fisheries (*Decreto 182/2004, de 21 de diciembre, por el que se aprueba el Reglamento de la Ley de Pesca de Canarias*).

each of these variables, the table indicates the stewards who mentioned the highest number of statements or practices, the most varied, or the most original.

Table 5. Diversity of perspectives, ecological knowledge and management.
Quantity: Stewards who mentioned the highest number of elements: A) more than 10 threats of a maximum of 21, B) more than 4 solutions of a maximum of 9, C) more than 8 statements of ecological knowledge of a maximum of 16, and D) more than 2 practices of a maximum of 4.
Variety: Stewards who mentioned the highest number of categories: A) more than 5 categories of a total of 10, B) more than 3 categories of a total of 6, C) more than 2 categories of a total of 5, and D) more than 2 categories of a total of a total of 4,
Originality: Stewards who mentioned the most original elements: A) threats mentioned by 1 or 2 stewards, B) solutions mentioned by 1 or 2 stewards, C) more than 4 original statements (those mentioned by 1 or 2 stewards) of ecological knowledge of a maximum of 8, and D) Management practices mentioned by 1 or 2 stewards.
O: official managers, G: guards, C: conservationists, L: land-based economic activities, S: sea-based economic activities (except professional fishers), PF: professional fishers, SF: sport fishers, R: recreation (except sport fishers).

	A) Threats			B) Solutions			C) Ecological knowledge			D) Management practices		
	Quantity	Variety	Originality	Quantity	Variety	Originality	Quantity	Variety	Originality	Quantity	Variety	Originality
O1												
O2												
O3												
O4												
G1												
G2												
C1												
C2												
L1												
L2												
L3												
L4												
L5												
S1												
S2												
S3												
S4												
S5												
PF1												
PF2												
PF3												
PF4												
SF1												
SF2												
SF3												
R1												
R2												
R3												

All steward groups provide some diversity even though the contribution differs among them. Official managers and conservationists provide the highest diversity in terms of perspectives and ecological knowledge, even though they did not mention original solutions. Such original solutions do not seem to be found in a particular LSG but in certain individuals. Diversity in terms of quantity and novelty of management practices is provided mostly by professional fishers.

Certain individuals in sea-based and land-based economic activities, recreational activities and sport fishers provide concrete sources of diversity, not showing homogenous contributions as LSG.

Knowledge sharing

Scientific and experiential knowledge is introduced and shared in the system by formal and informal networks of knowledge exchange. Two examples will be described here, the formal network of the Biosphere Reserve Consortium and the informal network around a conservationist NGO.

a) The Marcopalma project's formal network

The Marcopalma project led by the BRC had the main goal to assess the conservation status of the littoral areas of La Palma by collection of data about key indicative species, benthonic communities and human activities in the fringe between 0 and 50 meters under water (Martin et al. 2011). Other targets included analysing the evolution of the ecosystems inside the area of the Marine Reserve and describing the pressure of the human activities to the coastal areas.

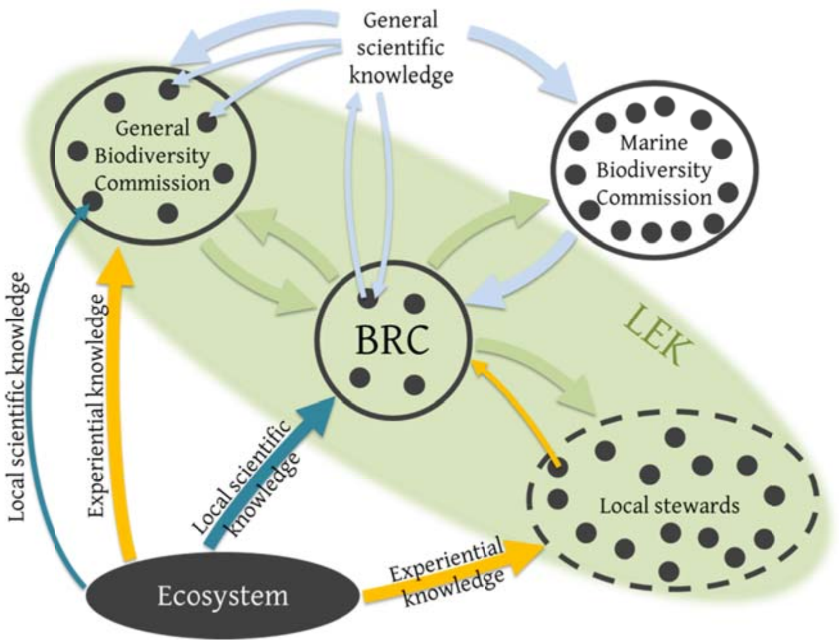

Fig. 11. Formal network of knowledge sharing of the Marcopalma project. LEK is nurtured by general scientific knowledge (light blue arrows), local scientific knowledge (dark blue arrow) and experiential knowledge (yellow arrow), i. e. knowledge derived from experience (Fazey et al. 2006). The BRC has a key role to gather and share this knowledge and nurture the body of LEK with mixed scientific and experiential knowledge (green arrows). Thin arrows are those concerning one individual and thick ones refer to a group of individuals. The circles with a continuous line show the BRC and the two consultative committees. The dashed circle embeds those local stewards not involved in the General Biodiversity Commission or the BRC.

Fig. 11 shows how the network around the Marcopalma project helped nurturing the body of LEK by direct collection of data from the near-shore marine ecosystem and by gathering existing knowledge from different sources.

Two expert commissions about biodiversity were consulted by the BR staff. The general biodiversity commission was a permanent board of local experts with members from universities, governmental organizations and acknowledged individuals from the island. In addition, the marine biodiversity commission was a body of experts on marine biodiversity established to give scientific advice for this particular project; this was formed by scientists from universities and representatives of the Canary Islands Government. Whereas the marine biodiversity commission provided non-local scientific knowledge, the general biodiversity commission would provide scientific knowledge validated and nuanced by local observation and experience. One member of the BR staff is linked to a university and shares knowledge with the scientific community by articles of the marine environment of La Palma and the Canary Islands.

The knowledge of the scuba divers was also included in the project by the BRC, who asked them about the location of certain species of interest. The Marcopalma project had a communication campaign through which the findings of the project were spread to local stewards and other stakeholders.

b) The conservationist NGO's informal network

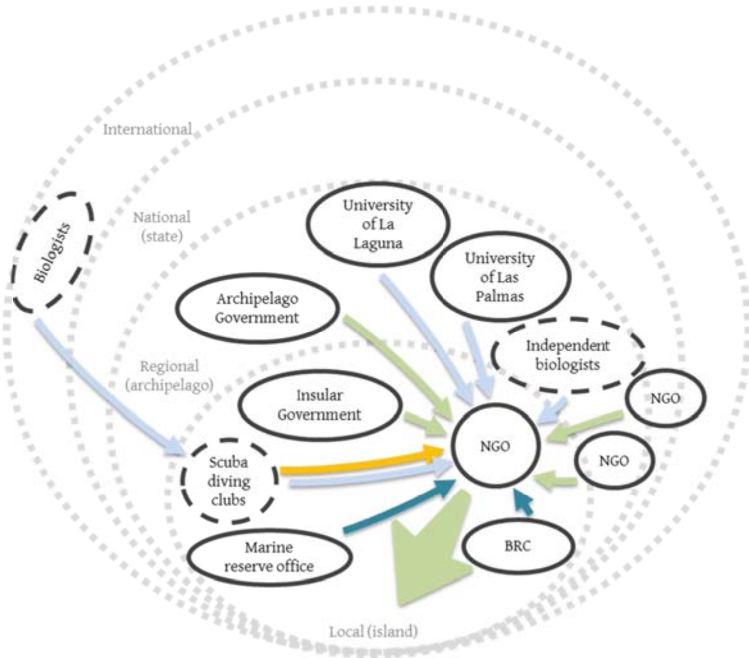

Fig. 12. Informal network of knowledge sharing around a local NGO. When a project potentially harmful for the marine environment is publicised, the NGO gathers information from sources at different scales providing general scientific (light blue arrows), local scientific (deep blue arrows), experiential (yellow arrows), and mixed (green arrows) knowledge. This knowledge is broadly disseminated in La Palma (thick arrow). The circles with continuous line show actors involved in one organization and the long-dashed circles show different actors representing similar kind of knowledge. The short-dashed circles show the different scales reached with the network.

According to the interview with a representative of an NGO (C1) and interviews with the BRC staff (O2), this local conservationist NGO mobilizes knowledge from different sources and scales when new projects with potential negative impacts to the marine environment are launched (Fig. 12).

The local informers are local governmental organizations and local scuba diving clubs. Information from regional scale is provided by the universities and independent biologists. The NGO offices based in other places of Spain provide links with the regional and national scale. Scuba diving clubs provide the link with international knowledge from foreigner biologists who have done field work in La Palma. This range of sources also provides a variety of kinds of knowledge, including local and general scientific, experiential, and mixed knowledge.

After consulting these sources, reports and press releases launched by the NGO disseminate the knowledge gathered about the values of the ecosystems of La Palma, including understanding of the ecosystem and possible effects of the project.

DISCUSSION

What diversity of perspectives, ecological knowledge and management practices is provided by local stewards?

a) Perspectives

Local stewards share consensus when identifying the main threats to the ecosystem. All local stewards agreed in recognising that it is endangered. More specifically, a shift from a rich to a low biodiverse ecosystem was described by most stewards. They also agreed on the causes being overfishing, mainly due to the use of too destructive gears and non-compliance by fishers. Sea urchin outbreaks were commonly acknowledged as an indicator.

Local stewards also identified threats that have a less visible effect, like chemical pollution, or that could be potentially impacting in the future, like oil spills and climate change. Here is where they provided a broad range of alternatives, indicating awareness for the unknown and the unexpected.

Official managers provided the highest number of and more varied solutions. The rest of the groups have one steward each having some contribution to diversity of solutions. Provision of original solutions is a scarce attribute held by only three local stewards spread in different groups.

Consensus of mental models within groups is stronger for stewards doing recreational activities, professional fishers, conservationists and official managers. They showed more similarity in the categories of threats and solutions mentioned. The rest of groups had a more heterogenic mental model. This could mean that the actors within these groups are more connected, because dense groups tend to have more similar perceptions, as suggested by Crona et al. (2011) and identified by Mathevet et al. (2011) for the Water Board of the Camargue Biosphere Reserve (Mathevet et al. 2011)

b) Ecological knowledge

All local steward groups and all stewards interviewed but one showed ecological knowledge valuable for ecosystem management. The body of knowledge drawn from the informants shows that they have knowledge related to the five principles valuable for ecosystem management (Dale et al. 2000).

Among the five categories, local stewards showed more knowledge of disturbances. This could reflect a bias in the method used: the flow diagram. The questions asked, based on threats to the near-shore marine ecosystem and solutions, resulted in an emphasis on disturbances rather than other aspects of ecological knowledge. This approach also influenced the kind of information mentioned under the other categories.

Knowledge under *time*, *species* and *disturbances* categories is shared among LSG. Knowledge under *place* and *seascape,* on the other side, was only found to be held by certain individuals.

All official managers and conservationists expressed a large and varied body of knowledge. Professional fishers also showed a big variety in the kind of knowledge they had as a group. Original knowledge was held by conservationists and a professional fisher.

It is not defended here that the knowledge elicited from informants is the complete body of local ecological knowledge of La Palma, rather it provides evidence of its variety. Furthermore, it is not validated knowledge. The aim of this research was not to proof the reliability of the knowledge but to show its diversity.

c) Management practices

Half of the local stewards carried out ecosystem management practices of value for dealing with uncertainty and change. All professional fishers and stewards doing recreational activities provided qualitative monitoring whereas quantitative data was mostly monitored by official managers. One sport fisher also provided quantitative information of the status of the populations of certain fish species. Qualitative and quantitative monitoring carried out by stewards other than official managers seemed to fill the gaps of available quantitative data. Professional fishers also performed the most varied range of management practices, including the four categories analysed. Original management practices were provided by certain stewards and seemed to follow an individual rather than a group pattern.

Some local stewards consciously performed practices to deal with certain disturbances such as liberating fish captured in blind or lost pond nets, rescuing turtles, removing garbage from seabeds or eliminating sea urchins. However, the effects of these practices are limited. There was no group pattern, but rather seemed dependent on individual attitudes towards threats.

Despite the general agreement that the ecosystem is overfished, no practice was found of relevance in the backloop of the adaptive cycle. Practices fostering disturbances at lower scales and nurturing sources of renewal described in the literature (Berkes and Folke 2002 and Tengö and Belfrage 2004) refer to inland cultivating and herding systems. This could explain why this kind of practices is not found in a water system where economic activities are based on fisheries and on the use of the ecosystem for transport, sport, and recreation.

Examples of stewards providing long-time series of local observation and social for understanding ecosystem change described by Berkes and Folke (2002) were not found in this system. However, some stewards mentioned old relatives or peers when talking about the past changes in the marine ecosystem. Long-term local observation could be orally transmitted through stories from elders to children also in contemporary societies. Other stewards had witnessed themselves the reduction of fish abundance and the disappearance of certain habitats. Social memory is present in terms of understanding of big environmental change though not in the transmission of the pertinent experience. This is because the social-ecological system has not undergone such a crisis before. However, if similar disturbances had happened in the past, the lack of traditional knowledge in the system may mean that the knowledge of how to deal with them has been lost. This is the case of many systems, including another Spanish social-ecological system in Doñana (Gómez-Baggethun et al. 2012).

Management practices have been analysed based on the adaptive renewal cycle (Holling 1986, Gunderson and Holling 2002), leaving aside other management practices that could take place. Furthermore, targeted management were local practices based on individuals' behaviour. This discards all those practices embedded in larger institutions that potentially have an important effect to the ecosystem, such as the establishment of marine protected areas, fishing regulations, and closed seasons.

Despite the variety of behaviours among groups and local stewards, individual stewards doing management practices are found in all groups. For example, stewards doing sea-based and land-based activities have a poor contribution in terms of management activities, but some individual stewards do qualitative monitoring and practices that build insurance against disturbances.

d) Diversity

Official managers and conservationist NGOs, i.e. the steward groups who work every day in ecosystem conservation, provided the highest diversity in terms of awareness of threats, proposed solutions and ecological knowledge. However, besides the threats mentioned, they did not seem to provide much originality.

The lack of diversity in management practices carried out by official managers and conservationists could be filled out by professional fishers. They also showed a high diversity in terms of the ecological knowledge provided.

Original solutions, knowledge statements, and management practices are provided by certain individuals of the rest of the LSG. In this case, it was individuals, not groups, who had important contributions.

Local steward groups with more rare contact with the marine ecosystem, i.e. stewards in sea-based and land-based economic activities, also appeared to give valuable contributions. For instance, they provide original solutions, a scarce attribute in the studied system.

What particular stewards will provide more diversity cannot be known a priori. Whereas the contribution by conservationists, official managers and professional fishers was acknowledgeable, the rest of groups provided diversity mainly on an individual level. Originality in qualitative and quantitative monitoring, for instance, was a feature provided by individuals. Therefore, to guarantee the highest diversity, the maximum number of stewards would need to be incorporated.

Aiming for the inclusion of the maximum number of stewards for ecosystem management would also guarantee redundancy, i.e. “the capacity of functionally similar elements to partly or fully substitute for each other” (Biggs et al. 2012). If one steward disappeared from the system, another steward with similar role could take over. This could be the case of stewards of two different conservationist NGOs, one of them having a more prominent role than the other.

As argued by Kofinas (2009) for social-ecological governance, La Palma case study shows that bringing a diversity of stewards together could foster innovative outcomes for ecosystem management. However, aiming to embed this diversity can be time-consuming and costly. The proportion between investment of resources and involvement of local stewards to provide diversity needs to be balanced.

How connected?

Networks mobilize local stewards and generate local ecological knowledge (Hahn et al. 2008). Two described networks of knowledge sharing show how local stewards are involved in nurturing the local body of ecological knowledge. They also show how different sources of knowledge are gathered and translated into the local body of ecological knowledge. Fig. 13 shows that local stewards in La Palma not only generate experiential knowledge but also create local scientific knowledge in form of official reports and scientific papers.

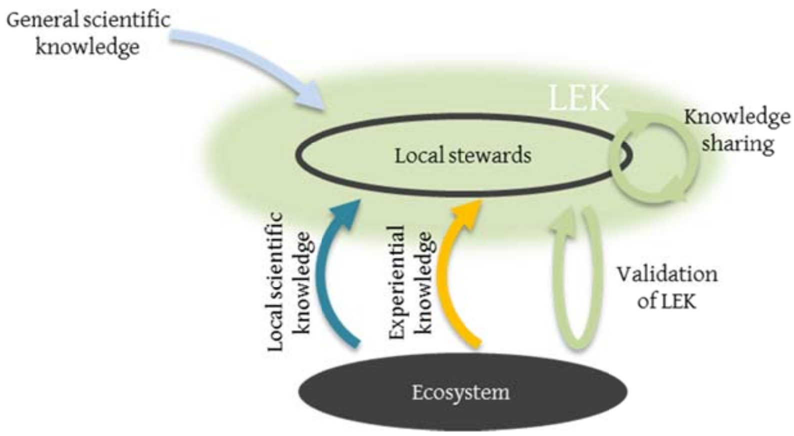

Fig. 13. Generation of the body of local ecological knowledge of the marine ecosystem of La Palma. General scientific (light blue arrows), local scientific (deep blue arrows), and experiential (yellow arrows) knowledge are inserted and distributed in the local system. Local stewards contribute in validating the knowledge that enters the system and sharing this mixed knowledge (green arrows) that builds the local body of ecological knowledge.

The BRC has actively increased the connections among local stewards, acting as a catalyst for knowledge generation and exchange. Moreover it has brought together different sources of knowledge, including local and general scientific knowledge, and experiential knowledge.

The short history of the BRC and the network created through the Marcopalma project, ten and five years respectively, implies that it may be still too early to see the effects of this knowledge sharing in management. However, from the capacity of the BRC to bring stewards into the management it can be inferred that there is potential for learning. Access to knowledge at upper scales is achieved by the network provided by a local conservationist NGO.

An effort has been done to see inconsistencies among responses and they have not been found. The diversity of perspectives, knowledge and management practices are not contradictory in general. This indicates that different contributions have the potential to be combined. As an exception to that, the perspectives of professional fishers and sport fishers can be contradictory when pointing out the causes of fish decrease. In general, both sport and professional fishers pointed out non-compliance of professional and sport fishers as main drivers leading to overfishing. However, one professional fisher only mentioned furtive sport fishers being the problem behind overfishing. Similarly, one sport fisher only suggested the use of nets in illegal settings by professional fishers as the main problem.

The social networks have been described in terms of knowledge exchange among different sources and scales. These networks could also provide links to combine perspectives and management practices and build on more shared mental models. High density of relations among actors can result in homogenization of mental models and knowledge (Bodin and Noberg 2005, Crona and Bodin 2006). Therefore, attention needs to be given to avoid loss of diversity as a result of too connected networks.

CONCLUSION

The study shows that local stewards in the near-shore marine ecosystem of La Palma consensually agreed on defining the ecosystem as degraded, the main driver being fishers' non-compliance, and the consequence being overfishing. The replacement of rich seaweed stands by sea urchin barrens was identified as an indicator of degradation.

Beyond this, stewards expressed a diversity of perspectives when it comes to threats identification and possible solutions. Embracing this diversity for ecosystem management would add preparedness for unexpected outcomes of the social-ecological system and novelty for coping with them.

Local stewards also showed to have a diversity of ecological knowledge and perform management practices valuable for ecosystem management. A particular finding is that not only official managers, but also other local stewards perform quantitative monitoring.

Official managers, conservationist activists, and professional fishers expressed the most extensive ecological knowledge. The other local steward groups appeared to be important for providing original knowledge, i.e. most scarce knowledge. Literature on adaptive co-management argues for the need to combine different knowledge systems, including scientific, traditional and local. Here it is argued that not only are efforts needed to combine these knowledge systems, but also to make sure that they are as broad and comprehensive as possible.

Professional fishers, stewards who do recreational activities in the sea, official managers, and some individuals at other groups stand out for the management practices they carried out. The lack of practices enhancing conditions for ecological functioning and recovery could indicate the reduced presence of these practices in marine systems or systems other than cultivation and herding. Social memory was found in the oral stories transmitted from one generation to the next through local stewards with a life-long contact with the sea.

The Biosphere Reserve Consortium has a key role in combining different kinds of ecological knowledge and understanding through the social network built around the Marcopalma project. The informal network adds the connection to upper scales. This leads to a flow of experiential, local scientific and general scientific knowledge and has the potential to foster learning towards adaptive co-management of the marine ecosystem.

Involving representatives of all local steward groups can be of help to add diversity of approaches, knowledge and concrete management practices for ecosystem management. The link to channel contributions of key representatives of this diversity may deserve to be ensured by formal networks. However, this may be costly and time-consuming.

Informal networks could facilitate the linkage to the whole diversity provided by local stewards. What conditions allow the emergence and persistence of informal networks is a challenge for ecosystem management and a key question for future research.

Despite the benefits of gathering diversity, too strong and comprehensive networks may result in an unwanted homogenisation of mental models and knowledge. How to facilitate communication without losing diversity needs to be further studied and discussed.

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APPENDIX 1. INTERVIEW GUIDE

Section 1

1. What is the most valued aspect of La Palma landscape?
2. What is the most valued aspect of La Palma near-shore marine ecosystem?

Section 2

3. What are your motivations for daily activities?
4. What are your regular activities related to the sea?
5. How did you learn the required knowledge to carry on these activities?
6. How do you get new knowledge to improve your these activities?

Section 3

7. What are the main features of the near-shore marine ecosystem? / Describe how the near-shore marine ecosystem is.
8. How has the near-shore marine ecosystem changed as far as you can remember?
9. How had it changed before?

Flow diagram

1. What are the main threats affecting the near-shore marine ecosystem?

   Follow-up questions: Why/how does it affect?
2. What are the solutions to the mentioned threats?

   Follow-up questions: Why/how would it solve the threat?

APPENDIX 2. FLOW DIAGRAMS: THREATS AND SOLUTIONS IDENTIFIED BY LOCAL STEWARDS

Threats

		O1	O2	O3	O4	G1	G2	E1	E2	L1	L2	L3	L4	L5	S1	S2	S3	S4	S5	PF1	PF2	PF3	PF4	SF1	SF2	SF3	R1	R2	R3
Overfishing	Sea urchins	X	X			X		X	X			X	X			X	X		X		X	X	X	X		X	X	X	X
	Damaging gears		X	X	X	X	X	X		X	X	X	X		X		X		X		X	X	X	X	X	X	X	X	X
	Non-compliance				X	X		X	X			X		X	X		X	X		X	X	X	X	X	X	X		X	X
	Sport fishing		X					X	X								X				X	X	X			X			
	Fishing in general	X			X		X																					X	
	Professional fishers' lack of responsability					X								X															
	Too many boats																					X							
	Lack of control								X	X		X																	X
Pollution	Plastic from banana crops			X				X																		X			
	Phytosanitaries and fertilizers			X			X	X	X					X		X						X	X	X		X		X	
	Oil (oil tankers, oil rigs)		X	X	X		X		X	X	X			X					X	X		X						X	
	Waste from fishers				X	X								X			X		X	X	X				X				
	Industry							X						X		X													
	Garbage dump							X						X						X									
	Lack of management							X																					
	Sewage		X	X	X		X	X	X					X						X				X				X	
	Nuclear spill, radiation		X		X									X															
	Other chemical pollution				X									X									X	X					
	Other waste				X		X		X	X					X	X	X	X	X	X		X	X	X					X
	Waste from construction								X															X					
Coastal development	Harbours and marinas		X	X	X			X	X		X			X		X											X		X
	Artificial beaches		X		X			X	X		X																		X
	Hotels, houses	X	X	X	X			X	X																			X	
	Habitat destruction		X	X	X				X					X															
	Means of access (roads and other facilities)	X																											
	Pollution derived from coastal development													X															
	Impact on currents and sand								X							X											X		X
Aquaculture	Invasive fish	X		X				X	X				X	X		X				X									
	Antibiotics, spread of diseases			X				X	X																				
	Change of wild fauna's feeding habits			X				X	X																				
	Landscape impact			X																									
	Impact on seabed								X																				
	Wild animals entangle with nets								X																				
	Uncertain source of fodder (chemicals)								X																				
Transport	Hits to cetaceans						X						X																
	Noise, pollution				X		X											X											
Climate change	Increase of temperature, radiation		X				X																						
	Rise of sea level		X				X																						
	Change of ocean currents		X				X																						
	Change of species abundance		X				X																						
	Changes in storms		X																										
Others	Other invasive species	X		X									X																
	Change of Law of Coasts								X																				
	Greenhouses (visual impact)															X													
	Mass tourism												X		X														

The first column indicates the main categories of threats to the near-shore marine ecosystem mentioned by informants. The second column shows statements they used to describe such threats, being causes, effects, or indicators of the threats. The upper row indicates the informants.

Solutions

			O1	O2	O3	O4	G1	G2	C1	C2	L1	L2	L3	L4	L5	S1	S2	S3	S4	S5	PF1	PF2	PF3	PF4	SF1	SF2	SF3	R1	R2	R3
Overfishing	Increase knowledge and raise awareness	Rise awareness, education			X	X	X	X	X	X														X			X	X	X	X
		Promote selective gears							X																					
		Promote sustainable tourism							X	X																				
		Promotion of existing Marine Reserve								X																				
	Management	Planning		X		X																								
		Quotas for sport fishing		X																										
		Closed seasons			X									X	X								X	X						
		(Rotatory) Microreserves							X	X			X		X									X						
		Local management instead of centralized													X															
		Campaings for killing sea urchins																						X						
		Subsidies for fishers														X					X									
	Legislation	Legislation		X		X		X	X			X											X			X	X		X	
		Regulation or prohibition of most damaging gears		X	X		X		X					X	X							X	X	X	X	X				
		Forbid to fish some species		X																										
	Control	Control			X	X	X	X	X		X		X	X		X		X	X	X	X	X	X	X	X	X	X		X	
	Compliance	Compliance to existing regulation			X	X												X											X	X
	Others	Research												X																
		More engagement from politicians																X						X						
General	Increase knowledge and raise awareness	Increase politicians' awarenness						X	X																					
		Knowledge management based on scientific and practitioners' knowledge with public participation	X																											
		Comunicate and rise awareness	X																											
	Management	Economic incentives for green behaviour							X																					
		Management tools to predict, assess and monitor	X																											
		Planning	X																											
	Legislation	Improve legislation for conservation						X																						
		Legislation	X																											
	Control	Control	X																											

The first column indicates whether the solution was mentioned to solve overfishing in particular or the set of threats of the marine ecosystem in general. The second column indicates the main categories of solutions mentioned by informants. The third column describes the concrete measures proposed. The upper row indicates the informants.

APPENDIX 3. ECOLOGICAL KNOWLEDGE HELD BY LOCAL STEWARDS

Ecological Principle	Statements of ecological knowledge
Time	Fish stock has decreased over the last years (12) The algae coverage, *Cystoseira abies-marina* in particular, has decreased over time (7) The conservation status of the marine ecosystem in the marine reserve has improved since it was established in 2001 (7) The population of sea urchins has increased (6) Some weather events like storms and the fair weather of September have changed their periodicity patterns, being less predictable (3) Loss of fish diversity (2) Sea urchin suffer epidemics (2) Density of sea urchins fluctuates over time (2) Change of temperature favours the presence of sea urchin (1) Fish abundance varies over time (1) There have always been good and bad periods for fishing, lasting 2-4 years (1) The shoreline changes over time (1) Algae coverage changes over time (1) Fish comes with the tides (1) *Cystoseira abies-marina* used to appear strong and shiny after rough sea (1) An invasion of jellyfish used to happen in April (1) In May, *Cystoseira abies-marina* was more visible (1) September was time for storms (1) Some years there's more *Cystoseira abies-marina* than others (1) The parrotfish spawns in March, April, May (1) The fishing season has been delayed last years (1)
Species	Key predatory species control sea urchins populations. For example, *Lepidorhombus boscii*, *Pimelometopon maculatus* and *Chilomycterus atringa* among others (12) Sea urchin outbreaks reduce algae coverage (9) *Cystoseira abies-marina* has a key role to sustain the marine ecosystem (7) Certain alien species can affect local fish by competition or predation. In particular, the species used in aquaculture (5)

Place	Since it is a thin fringe, this insular platform is vulnerable to disturbances (4) Rocky sea beds support macro algae-based ecosystems with the richest biodiversity (3) The underwater insular platform is the area with the highest biodiversity (3) Waters are relatively warm, therefore primary production is low (1) Some areas at the North are less accessible for fishers, this helps to protect fish (1) Water temperature affects presence of parrotfish and in turn presence of sea urchin (1) Caves create favourable conditions for the presence of lobster (1)
Disturbances	Solid waste harms marine fauna by consumption and entangling (9) Overfishing key species leads to sea urchin outbreaks (8) Modernisation of boats and fishing gears lead to overfishing (8) Coastline development destroys habitats and ecosystems (7) Pond nets are a particularly harmful gear because they harvest a high amount of fish (6) Lost pond nets are a particular problem since they are a never-stop killing machine (6) Certain alien species from aquaculture predate on local fish (5) Overfishing has reduced fish abundance (4) Fishing rates exceed the recovery rate of the fish population (4) Changes in temperature provoke changes in species (4) Coastline development modifies water currents (3) Chemical waste accumulates in the trophic net (3) Antibiotics from aquaculture can change the ecosystem (2) Aquaculture changes the feeding behaviour of fish (2) Overfishing reduces biodiversity (2) Alien species from aquaculture can compete with local fish (2) Aquaculture Destroys the grounds (2) Overfishing leads to sea urchin outbreaks (1) Overfishing changes the structure of the whole ecosystem (1) Dynamite fishing is very harmful for the ecosystem (1) The volcano in 1976 changed the sea beds and created more caves (1) Fishing gears destroy coral (1) Pond nets damage the grounds (1) Blind pond nets destroy the grounds (1) Oil spill impacts marine birds (1) Oil spills can impact fauna by suffocation and flora at a molecular level (1) Alien species from aquaculture can impact the trophic net (1) Aquaculture can impact local fish by getting entangled with the nets (1) Acoustic pollution damages cetaceans (1) Liquid waste harms filtering animals (1) Sewage change the structure of the ecosystem (1) Sewage can eliminate certain species (such as the coloured sea urchin)

	(1) Liquid waste can produce eutrophication leading to fish death (1) Marine transport can lead to accidents with cetaceans (1) Phytosanitaries can accumulate in the trophic net (1) Phytosanitaries from banana crops damage fauna (1)
Seascape	Fishing in other regions affects the amount of fish in La Palma (1) Alien species from aquaculture in La Palma can migrate to other islands (1) Increase of biomass in the Marine Reserve improves biomass in near areas (1) Presence of Mediterranean, Caribbean and African fauna (1) No possibility to recover the fish once it is exhausted (because the platform is thin) (1) When Japanese and Korean boats started to fish at Guinea Golf, they finished with the migrations of the tuna (1)

Local ecological knowledge held by local stewards in La Palma divided into the five principles important for ecosystem management (adapted from Dale et al. 2000). The number of local stewards saying each statement is shown in brackets.

APPENDIX 4. DISCUSSION OF METHODS

A place-based case study allowed in-deep understanding of the social-ecological system and detailed information of individual stewards' cognition and behaviour. It also permitted to understand the local ecosystem management organizations, in particular the BRC. An alternative to that approach would have been a thesis based on comparison of a number of different cases. This would have provided information of a more diverse settings and populations, and would have probably helped to generalize the findings. However, the results would have been broader and less nuanced.

The broader institutional setting was not studied either. This would give a better understanding of the way local stewards relate to the ecosystem. Potentially, it would also give information of the leeway of both official and non-official local stewards for managing the ecosystem.

The flow diagram technique was useful to gather knowledge mostly based on threats and solutions. Therefore, knowledge elicited was knowledge useful for ecosystem management in the face of change and from an ecosystem approach, allowing the emergence of complexity. Local stewards may have more ecological knowledge than captured useful for ecosystem management and for their daily activities.

During interviews, several factors influenced the amount of information captured from each interviewee. Some constraints were time availability and traits of the interviewee (openness, mood, and engagement to the research), and the author's interpretation when categorising.

The author's ability to do follow-up questions during the interviews and following the threads of the flow diagram could differ from one interview to another and improved over time, thus affecting the amount of information elicited. Therefore, the differences of contributions among local stewards studied here need to be understood as indicatives.

The discussion about diversity among LSG indicates trends from a qualitative approach. Statistical analysis was discarded because the number of individuals in each category is reduced and doesn't allow drawing quantity-consistent results.