Ecosystem Services 17 (2016) 1–4

Contents lists available at ScienceDirect

Ecosystem Services

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

The role of marine ecosystem services for human well-being: Disentangling synergies and trade-offs at multiple scales

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ARTICLE INFO

Article history:
Received 29 October 2015
Received in revised form
30 October 2015
Accepted 31 October 2015

Keywords:
Marine ecosystem services
Synergies and trade-offs
Multiple spatial scales

ABSTRACT

With the advance of ecosystem services (ES) assessments, the existence of synergies and trade-offs between services became clear. However, identifying these conflicts and potentials correctly and estimating the impacts of simultaneous use or of favoring one service to the detriment of the other is not a simple task. Among marine ecosystem services, the challenge is probably larger, given the invisible nature of some of the resources and services provided, and the fact that we do not have full control over such a huge habitat. In this Special Section we attempt to discuss some of these synergies and trade-offs at different geographical scales, from local case studies to multiple ecosystem assessments, and from cultural to provisioning ES. Along twelve papers, different frameworks, theoretical approaches and statistical tools are developed to show the state-of-the-art in ES assessment in developed and developing countries. Together, these studies bring a new diagnosis at local scales, where marine protected areas can or not interact synergistically with other services, such as fishing and tourism, depending on the institutional strength and proper development of social capital. Overall, this special issue presents multiple recommendations that can redirect policy-making regarding the best use of ES around the globe.

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1. Introduction

Ecosystem services (ES) are the conditions and processes through which natural ecosystems and the species that inhabit them support the survival of the human species (Daily, 1997; Duarte, 2000). Globally, these conditions and processes maintain biodiversity and the production of goods (e.g., food) and services (e.g., waste assimilation) that contribute to human welfare (Costanza et al., 1997; Naidoo et al., 2008). While ES provided or used in land have been getting considerable attention, the uses, conflicts and synergies in marine ESs are still somehow unexplored (Halpern et al., 2012; Worm et al., 2006).

However, not knowing enough about marine ES is worrisome, because they provide a wide range of benefits to society: food, income, employment and entertainment among others. Food security and human wellbeing are undoubtedly linked to the quality of marine ES (FAO, 2014a), especially to the so-called provisioning services such as food, water, and fuel. Marine and costal ES (including coral reefs, marine and coastal waters and open access) have also been shown to provide the highest economic benefits to the world population. In the same line, a recent study updated the economic value of ES at global scale and compared the estimates made in 1997 to the one in 2011 (Costanza et al., 2014). The authors highlighted that the world experienced an economic loss of USD 19 trillion/year in the 1997-2011 (from UDS 60 trillion/year in 1997 to 49.7 trillion/year in 2011).

The delivery of many of these ES is dependent on human uses and environmental changes, which pose critical challenges for future food production and income generation. Therefore, maintaining long-term food security, supporting poverty alleviation, and keeping the cultural relevance of marine areas is strictly dependent on assuring healthy and resilient ES (Nellemann et al., 2009).

Nevertheless, many ecosystems are already under stress due, for example, to overfishing and unplanned coastal growth that compromise marine biodiversity (Costello et al., 2010). Overfishing has already compromised most of the stocks over 3 billion people depend upon (FAO, 2014b), while exacerbated coastal development affect from the meiofauna to any vertebrate, including mammals, due to stressors such as sand grooming, pollution, exploitation, biological invasion and engineering, among others

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http://dx.doi.org/10.1016/j.ecoser.2015.10.022
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(Defeo et al., 2009). Besides, external anthropogenic drivers, such as climate change, are likely to exacerbate the worsening conditions of ES in many coastal areas. Climate change can, for example, acidify the oceans and cause coral bleaching, which can affect fisheries, increase the vulnerability of coastal protection, decrease the value of tourism (Moberg and Folke, 1999; Roessig et al., 2005), and decrease food security (Boelee, 2011). However, simply being aware of these issues is not enough to make a change: without qualitative and quantitative assessments and the adoption of incentive mechanisms for conservation, marine ESs are still seriously underestimated by both users and government authorities (Nelson et al., 2009).

While the valuation of ESs is a necessary step to be recognized as a relevant component of environmental public policies, we still need to understand how the simultaneous uses of marine ES interact. In some cases, such interactions can be positive, such as ecotourism and biodiversity conservation, but in others, especially when there is resource consumption by humans, such as in fisheries, there can be conflictive interactions. The removal of biodiversity, for example, depending on how and to what extent it is made, can compromise the offer of other services, and vice versa (Worm et al., 2006). This is characterized as a trade-off, because society will need to make a decision regarding when, how and how much of each ES will be used, with likely short or long-term consequences on the benefits derived from them. We are at a point though that identifying these conflicts correctly and estimating the impacts of favoring one service to the detriment of the other is not a simple task, but nonetheless a challenge that we need to face.

In this Special Section, we put together a collection of studies that approached synergistic and conflicting uses of marine ES at different geographical scales (from villages to nations) and that encompassed an array of ES (wildlife watching, ecotourism, fisheries, aquaculture, use of the space by harbors and marinas, among others). Although there is still a long way to go, we hope that this is an important contribution to advance the understanding of marine ES and the making of new policies to regulate their use.

In the first paper, Barnes-Mauthe and collaborators explore the view that social capital should be understood as an ES as well, under the umbrella of cultural ES. The authors build their argument based on the fact that social capital affects and gets affected by natural resources and other ES. For example, by helping build cohesion and exchanges in a community, social capital can enable the establishment of common rules and facilitate natural resource management. Just like any other ES, social capital could be augmented or depleted, as an outcome of changes in the flows of other ES. Their case study is developed in Madagascar, in Velondriake, the first collaborative locally managed marine area (LMMA). By using Discrete Choice Experiments, the authors show that the establishment of a LMMA increased the levels of social cohesion within the villages, which in seen in their trust in each other, besides improving the relationships and respect between villages. In its turn, such higher levels of social capital facilitated the management of the marine area.

The second paper of this Special Section addresses the role tourism could play in directing management measures to solve an interesting human-made problem: an overpopulation of kelp gulls feeding on the flesh of live southern right whales in the protected area of Península Valdés (Argentinian Patagonia). The excess of kelp gulls is due to inappropriate waste management in the area, with open area disposal sites. A high number of tourists visiting the area do it for cetacean watching tourism and the view of kelp gulls feeding on live whale calves can be detrimental. In this study, Stefanski and Villasante investigate tourists' Willingness to Pay (WTP) to address such issues, based on the assumption that tourists are part of the problem (tourism generates waste and demand for products otherwise absent), and that the problem itself could potentially decrease tourism in the future. Tourists were offered an option to pay for a management plan to address the problem, either to cull the gulls or to fix the waste problem. The interviewees are more willing to support the general plan and the waste management plan than to support culling the gulls. The rejection to culling the gulls is due to most of the tourists traveling to the area for the biodiversity itself, and would not appreciate being part of something that includes removing part of this biodiversity, even if it is a problem. International tourists show a slight different view than Argentinians. They are, for example, even less willing to pay for culling the gulls, and among those foreigners who would refuse to pay any extra money for the waste management plan, there is the view that this is the city's responsibility and not the tourists'. Overall, the fact that tourists would be willing to pay to ameliorate the problem could be part of the solution for the conflict in local wildlife tourism.

In the third paper, Cabral and collaborators do a thorough assessment of the vulnerability of the ES being used in Normand-Breton Gulf in France, specifically of those provided by benthic habitats. For that, the authors use a modeling tool specifically developed to assess ES: the InVEST Habitat Risk Assessment, which, besides assessing the status quo (baseline), also allows them to create scenarios with increased use of ES (development scenario) and with more conservative uses (conservation scenario). The baseline and scenarios are created according to estimates of mapped physical, chemical and biological pressures in marine habitat as a proxy of the habitat potential to provide ES. Clearly, such scenarios also spatially described the pressures on the entire benthic habitat considered. The development scenario exposes the risk of increased vulnerability for ES people depend upon in the area. Among all ES considered, fishing is the one that demands more habitat space and therefore the activity that demands more attention from policy-makers, because it can both impact and be impacted by the habitat condition. The results of this study highlight clear spatially mapped interactions in the use of ES, simulating increased or decreased trade-offs, depending on the political strategy adopted (developmental or conservationist).

In a turn of tide, Indonesia seems to be paving the way for more synergistic interactions in the use of ES. After a long history of heavy fishing relying on very destructing methods, such as dynamite and cyanide poisoning that threatened the local livelihoods, Indonesia is discovering the benefits of reef conservation. This is the issue that Heber approaches in the fourth paper presented here. The author investigates why two similar villages, Pemuteran and Lovina, which undergo the same historical fishing exploitation and that adopt a conscious effort to recover their reefs through community based initiatives roughly at the same time, face very different rates of reef recovery. Such differences are important, because they determine the income and revenues brought by tourists, who would clearly prefer sites where reefs are healthier. Tourism and biodiversity conservation, with sporadic fish provision for the local diet, are synergistic services that need to be deeply understood to assure that people do not fall back into destructive fishing practices again, which has been observed during periods of Indonesian economic crisis. The differences observed between the villages are attributed to different institutional backgrounds. In Pemuteran, for example, there is greater outside stakeholder involvement, such as NGOs, with a history in supporting local reef conservation. NGOs help the village to bring more money in and to write grants. On its turn, the village also gets more recognition, through international awards, which works as a constant reminder to local people of the benefits brought about by conservation.

Drawing on a similar issue, but this time in Brazil, the fifth paper by Lopes and collaborators approach the conflicting and

synergistic uses between fisheries, marine tourism and biodiversity conservation. In the Ilha Grande Bay (Rio de Janeiro state), small-scale fisheries are in direct conflict with a marine protected area that has not clearly delivered biodiversity benefits to society. For example, some high-valued species, such as groupers, can be more abundant in areas outside the limits of the protected area. This is partially so because fishers do not agree with the choices of the islands to be protected, therefore, the poaching of reefs and islands remains. On the other hand, fishers that struggle to include tourism in their ES portfolio now thrive much more than the ones who still stick to fishing only. The authors suggest that conflicts, in this case, are easily solved problems and, if done, could support local poverty alleviation. First of all, tourism and work diversification in general would need to be incentivized for those who perform solely fisheries. Second, it is necessary to fix a faulty market chain that wastes fish and decreases its value. If that is done, fishers would not need to fish as much for the same gain, perhaps given a chance to the protected area to deliver its potential service of working as a spillover source of fish to nearby areas.

In the sixth paper, Outeiro and colleagues use the potential of InVEST Overlap marine models to spatially map the distribution of marine ES (ecotourism and recreation, wildlife endangered species and habitat-forming species) in the Southern region of Los Lagos (Chile). This study also uses the development of other plausible future conservation and industrial development scenarios as a way to navigate into resilient transformations of this marine social–ecological system. Due to changes in the strategic economic development paradigm for the area, decision makers, the scientific community and industry representatives are facing a major challenge in allocating appropriate areas to secure ES which requires a holistic perspective.

In another contribution, Outeiro and collaborators evaluate the spatial distribution of marine ES with emphasis on the aboriginal communities in Southern Chile. In particular, the study provides empirical evidence about the use of traditional ecological knowledge (TEK) of aboriginal communities in order to integrate it into social–ecological assessment of marine ES. The authors also show that this constitutes a broad body of knowledge that impacts a wide spectrum of ES, benefits and cultural values in the area, demonstrating that ecological management practices in local communities are strongly framed by social thresholds. The customary tenure system emerged from the aboriginal communities opened a new window of opportunity to show the attributes of TEK managing marine ES synergistically, with the dynamics of the economic demand of other provisioning services such as fisheries and aquaculture.

In the eight paper, Villasante and collaborators use the ES framework to study how rural aquaculture is contributing to the reduction of hungry and poverty in Africa. By using a participatory approach in local communities of Angola and Mozambique, the paper shows that rural households are strongly dependent on agriculture/aquaculture as their main source of food and income. In general, families making a living from fish farming as their main activity have improved their access to food and basic services. There has been a substantial increase in fish consumption in households since they have been engaged in rural fish farming, and there has also been an increase in the frequency of fish consumption. However, rural aquaculture is still a sector in an early stage of development and has to overcome limiting factors such as a lack of specialized technical knowledge, logistical infrastructure and difficulties in access to microcredit and seafood markets.

In the ninth paper, Jacobs and others introduce a knowledge based ES screening, applied in a participatory manner by including different stakeholders from four industrialized NW-European estuaries in Belgium, Germany, and the United Kingdom. The study shows that key ES for four industrialized estuaries are determined based on a broad demand survey among regional working group experts of four estuaries. ES-demand in the four estuaries is remarkably similar. In addition, the paper also points out that differential supply of ES by habitats invokes trade-offs between ES-supplies when habitat surfaces change at different spatial and temporal scales. As ES are delivered by different (combinations of) habitats, trade-offs and synergies emerge.

In the tenth paper, Alonso Roldán and colleagues use the social network analysis (SNA) to investigate the links between ecological and social nodes in Central Patagonia (Argentina). SNA has proven to be useful tool in studying and explaining social phenomena to provide an innovative framework to analyze the social dimension of marine social–ecological systems. By focusing on organizations and institutions with competences on continental and marine ES, the authors highlight that use and governance relations among social actors showed similar structures with cohesive and centralized patterns, while municipalities were the actors with the highest use of ES, although they were not the actors with the highest participation in the of governance of ES. The paper also demonstrates that social networks are useful tools to highlight gaps and paths to move the system toward more effective co-management structures.

In the eleventh paper, Selig and collaborators evaluate the potential of using the Ocean Health Index (OHI) framework (Halpern et al., 2012) in a finer scale, i.e., small countries, such as island nations which are usually data-limited places. Specifically, the framework was applied to Fiji, an island nation that depends on fisheries and tourism mostly done inside marine protected areas, but still threatened by inappropriate water and land use. Although still depending on some world data to refine the framework, the authors improve the quality of ES evaluation that are more important nationally, such as food provisioning, and data that are relevant for multiple indicators and sub-indicators of the OHI, such as coral condition data. The authors show that some of their assessed ES, according to the OHI framework, have potential to increase their exploitation, such as mariculture and the use of natural products. On the other hand, they highlight that intensifying the exploitation of such ES could result in negative impacts on biodiversity. Their results reinforce the idea that such a global framework has potential to be applied to finer scales where data availability is usually limited.

Finally, in the last paper of the Special Section Kleisner and collaborators apply a novel statistical methodology (the nonparametric statistic Kendall's tau) to assess the biomass of exploited marine species across marine ecosystems (spanning from upwelling, high-latitude, temperate, to tropical marine habitats) and evaluate changes in fisheries through comparative assessment of community degradation. This study emphasize the fact that fisheries provide a critical provisioning service from marine ecosystems and thus understanding where fish communities are declining provides an indication of concern for the ecosystems. This degradation could also highlight potential conflicts between seafood provisioning from wild capture fisheries and other ES. In the study, the proportion of 'Non-Declining Exploited Species' (NDES) is used to compare patterns in the states and temporal trajectories of the exploited species of marine communities. Three community-level indicators that capture the delivery of both provisioning and supporting ES are used to make comparisons between population and community status: survey-based mean trophic level, proportion of predatory fish, and mean life span. Overall, results show that the NDES indicator corresponds to states and temporal trajectories of the community indicators, indicating deteriorating conditions in both the exploited portion of the community and the overall community. However differences illustrate the necessity of using different ecological indicators to reflect different facets of

the state of the ecosystem and that the use of NDES required context-specific supporting information in order to provide guidance within a management framework.

Overall, the twelve papers presented in this special section considerably advance our understanding of trade-offs and synergistic interactions between ES, besides opening the perspectives for future studies. The potential of marine protected areas, for example, is highlighted in multiple studies, where it is shown that they can provide more opportunities for sustainable tourism and coral recovery, but also be a source of conflicts with fisheries if not properly managed and enforced. Different tools are also used or adapted to evaluate the multiple uses and vulnerability of ES, such as the Ocean Health Index, InVEST models, the NDES indicator, and econometric procedures and social network analysis, suggesting this is thriving topic with much still to be investigated. We hope that the contributions presented here will help sediment the first steps in the understanding of complex interactions between ES.

Acknowledgments

Our special thanks to all the authors and reviewers that contributed to the making of this Special Section. We also appreciate the constant assistance of the Ecosystem Services Journal during the whole process of organizing and publishing this section. SV acknowledges the financial support from the Spanish Agency for International Development Cooperation (AECID) (Grant no. 11-CAP2-1406) and the Galician Government (Consellería de Cultura, Educación e Ordenación Universitaria, Xunta de Galicia) (Grant no. R2014/023). MC acknowledges the financial support from the European Commission through the Marie Curie Career Integration Grant Fellowships – PCIG10-GA-2011-303534 - to the BIOWEB project.

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