Resilience and Challenges of Marine Social–Ecological Systems Under Complex and Interconnected Drivers

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Abstract In this paper, we summarize the contributions made by an interdisciplinary group of researchers from different disciplines (biology, ecology, economics, and law) that deal with key dimensions of marine social–ecological systems. Particularly, the local and global seafood provision; the feasibility and management of marine protected areas; the use of marine ecosystem services; the institutional dimension in European fisheries, and the affordable models for providing scientific advice to small-scale fisheries. This Special Issue presents key findings from selected case studies around the world available to educators, policy makers, and the technical community. Together, these papers show that a range of diverse ecological, economic, social, and institutional components often mutually interact at spatial and temporal scales, which evidence that managing marine social–ecological systems needs a continuous adaptability to navigate into new governance systems.

Keywords Resilience ·
Complex marine social–ecological systems ·
Local and global drivers

INTRODUCTION

This Special Issue is the outcome of the Special Session entitled “Resilience and marine social–ecological systems” organized at the 6th World Fisheries Congress held in Edinburgh (Scotland) in May 2012, completed with a few other relevant contributions. The Special Issue is composed of 13 papers dealing with economic, ecological, and institutional aspects of marine social–ecological systems in the modern management of fisheries and aquaculture activities. These papers examine local and

global drivers as well as how to cope with different challenges such as ensuring food provision while maintaining health of ecosystems and the flow of marine ecosystem services.

We have organized the contents of the Special Issue in four thematic areas that address some of the relevant questions concerning adaptive management of social–ecological marine systems: (i) local and global seafood provision; (ii) the feasibility and management of marine protected areas (MPAs); (iii) the use of marine ecosystem services; and (iv) the institutional dimension when managing marine social–ecological systems in European fisheries, and the affordable models for providing scientific advice to small-scale fisheries.

DISCUSSION

The first thematic area deals with the provision of food for humans that is derived from the sea or through aquaculture (Bené et al. 2010) and is composed of four papers. Kleisner et al. (2013) examine the sustainable provision of seafood either from wild-fishery captures or mariculture by using the so-called Ocean Health Index. The authors found that global patterns of marine ecosystems are positively related to human development and latitude of countries, whereas those for mariculture are most closely associated with economic importance of seafood. Sensitivity analyses show that these findings are robust to several model assumptions, but highly sensitive to choice of reference points and, for fisheries, the extent of extent of time series available to estimate landings.

The second paper deals with the emergence and consolidation of China as a new economic power and its large

impact on global fishery performance, not only in economic terms but also in social, strategic, and sustainability dimensions. Villasante et al. (2013a) examine the role of China in the seafood market at worldwide level. The results reveal that the rate of growth of China's per capita gross domestic product doubled that of other developing regions in the 1960–2010 period, while the per capita daily fish intake of China increased fourfold during the same time period. China is now the largest fish consumer, producer, and retailer of seafood products in the world. Given the size and scale of China's role in the production, consumption, and global transformation of seafood markets, the authors conjecture that China is shaping a new era of industrialization in the history of the fishing industry.

The third paper in this theme by Villasante et al. (2013b) points out that wild fisheries and aquaculture exhibit have a different pattern in terms of prices. While the price of wild-harvested species remains stable in the 1950–2010 period, the price of aquaculture species are higher and fluctuate more over the same period than the price of the same species when they are harvested from wild fisheries. The authors argue that three mutually reinforced factors may contribute to this different patterns: (i) the global fish conversion rate from wild-pelagic species to aquaculture production continues to improve over time due to a more efficient use of resources, (ii) the price of pelagic fish species to feed aquaculture species has increased, which in turn induces higher aquaculture prices, and (iii) the level of market concentration is significantly higher in aquaculture than in capture species, which ultimately generates higher prices in aquaculture species due to increased market power of large retailers. The fact that prices of wild-catch species and aquaculture species behave so different reveals that species from wild catches and aquaculture production are not necessarily close substitutes. Finally, the paper uses the case study of the Spanish seafood market to illustrate that a process of retail concentration induces increasing market power for a few key supermarkets and retailers which, at the end, increases consumer prices.

Finally, within this thematic group, Fröcklin et al. (2013) fill an important gap toward adaptive management of small-scale fisheries by analyzing the gender dimension of fish trade in Zanzibar, Tanzania. First, they hypothesize that gender-based differences are present in the fish value chain. Second, they test their hypothesis through interviews to analyze markets, customers and mobility, material and economic resources, traded fish species, contacts and organizations, and perceptions and experiences. Third, they study management documents to examine the degree to which gender is considered. The results obtained confirm that women traders had less access to social and economic resources, profitable markets, and high value fish than male traders, which resulted in lower income. Such gender

inequalities are linked, among others, to women's roles as mothers. Formal fisheries management was found to be gender insensitive, showing that knowledge about key actors and their needs and challenges is missing in Zanzibar's adaptive management system.

The second thematic area of this Special Issue contains four papers that provide new insights from adaptive management in the use of MPAs in developing countries like Brazil, Chile, and Colombia. Although MPAs have traditionally been regarded as an efficient alternative to protect natural resources and to improve fisheries (Armstrong 2007), they may also lead to negative socio-economic consequences for fishing communities. Both aspects are analyzed in the four articles of this section.

Lopes et al. (2013) examine the effectiveness of a socially conflictive MPA between stakeholders in Brazil. To that end, they assess target reef fish biomass in islands inside and outside the MPA, fisheries productivity (biomass), catch per unit of effort (CPUE), and fishers' income in three fishing communities subjected to different degrees of influence (close, average, and long distance) of the MPA. The findings show that CPUE is higher in the fishing community, that is, further away from the MPA, fish biomass is higher in the islands located inside the MPA in the southern region, and in the islands located outside the MPA in the northern region. The authors also found that fishers are making the most profit closest to the MPA, just where conflicts are the highest, probably from practicing very intensive fishing. This integrated approach illustrates that the studied MPA does not yet deliver clear ecological benefits, such as higher CPUE or more fish, and that higher income closer to the MPA cannot be clearly attributed to the MPA.

In the second paper of this theme, Gelcich et al. (2013) assess the role of visitor fees to generate the funds to manage a MPA in the temperate region of Chile. Both the international donors and the Chilean government supported development of nature-based tourism to generate funds for running and enforcing the MPA. The authors point out that almost all of the respondents were willing to pay an entrance fee aimed at management and environmental protection of the MPA. Significant predictors of tourists' willingness to pay included the type of tourist (nature-based or sun-sea-sand), sensitivity to crowding and, finally, education and understanding of ecological benefits associated to the MPA. Nature-based tourists were willing to pay 16 % more than sun-sea-sand tourists. The main conclusion is that, based upon official visitor numbers to the area, entry fees would not be enough to self-finance the MPA (only accounting for 10–13 % of running costs).

In the third paper of the MPA theme, Moreno-Sanchez and Maldonado (2013) define an index of adaptive capacity for the establishment of a MPA in Bazán—a fishing

community located in the Colombian Pacific. They carry out household surveys designed to get information for indicators and sub-indicators, and calculate the index. They also perform a sensitivity analysis to check for robustness of the results. Findings show that, despite being located between two MPAs, the fishing community is highly vulnerable and that the socio-economic dimension of the index constitutes the most binding dimension for building adaptive capacity. Bazán is characterized by extreme poverty, high dependence on resources, and lack of basic utilities. Notwithstanding, social capital and local awareness about ecological conditions may act as enhancers of adaptive capacity. The establishment of MPAs should consider the development of strategies to confer adaptive capacity to local communities highly dependent on resource extraction.

In the fourth paper of the MPA theme, Vásquez-Lavín et al. (2013) evaluate the feasibility of establishing multiple uses of MPAs in Chile. The authors evaluate three proposed sites with diverse conservation needs, social stress and poverty levels, and different economic activities (small-scale fishing, heavy industry, and mining activities). The methodology used combines data with personal interviews, workshops, and focus groups with stakeholders from different political, social, and economic backgrounds. Using this stakeholder's analysis tool, the authors characterize current and potential natural and social resources to evaluate the feasibility of establishing the multiple use MPA. This methodology identifies the challenges faced in each site and can be used to develop appropriate strategies for balancing economic, social, and environmental objectives.

The third theme of this Special Issue deals with the use of marine ecosystem services in marine social–ecological systems. The linkage between ecosystems and human welfare is a focus of the conceptualization of “ecosystem services” as promoted by the Millennium Ecosystem Assessment (MEA). However, the actual nature of such connections remains complex and poorly understood. In this thematic group, the use of marine ecosystem services is analyzed by focusing on the small-scale fisheries in Kenya and the salmon aquaculture in Chile.

In the first paper, Abunge et al. (2013) conduct a series of qualitative focus group interviews with five different stakeholder groups associated with a small-scale Kenyan coastal fishery in order to understand three issues: (i) how is wellbeing understood within the community and what is important for welfare, (ii) how has people's wellbeing been affected by changes over the recent past, and (iii) what are the people's hopes and aspirations for the future of their fisheries. The results show that people conceive wellbeing in a diversity of ways, but that these can clearly map onto the MEA framework. In particular, the research unpacks the “freedoms and choices” element of the framework, and argues for greater recognition of these aspects of wellbeing

in fisheries management in Kenya, through for example, more participatory governance processes.

In the second paper, Outeiro and Villasante (2013) conceptualize the synergies and trade-offs caused by the salmon industry on a range of ecosystem services, and quantify the impacts of the sector on provisioning and cultural ecosystem services. Despite improvements in average income and poverty levels experienced in communities associated with the sector, the progress is not large enough, and social welfare did not improve substantially during the 2000s. The rest of human wellbeing constituents in Chiloe region have not changed significantly compared to the development in the rest of the country.

The Special Issue ends with the thematic group related to the institutional dimension when managing marine social–ecological systems in European fisheries. First, Hadjimichael et al. (2013) highlight the links between institutional arrangements and ecological dynamics in two European inshore fisheries. The authors use the resilience framework (Anderies et al. 2004) and point out that Mediterranean small-scale fishers do not seem to have been particularly affected by the common fishery policy regulations. Instead, these small-scale fishers appear to be affected by competition with the politically strong recreational fishers and the invasion of the rabbit fish population. In the other fishery, the inshore fleet along the east coast of Scotland believes that their interests are not as sufficiently protected as the interests of their offshore counterpart. The authors conclude that decisions and initiatives at global, European, and sometimes national level, tend to take into account those fisheries sectors that have a national economic importance. However, a social–ecological analysis can shift the focus from biological and economic aspects to more sustainable long-term delivery of environmental benefits linked to human wellbeing.

On the other hand, individual transferable quotas (ITQs) have shown themselves to be fairly effective in generating economic rents in fisheries. In the second paper of this theme, Da Rocha et al. (2013a) show how the introduction of ITQs can alter agencies' incentives to deviate when time consistency problem exists. The authors show that agencies find it optimal to approve higher quotas than those proposed by scientific advice in European fisheries. Moreover, the paper shows that the introduction of ITQs increases the potential benefits for agencies of deviating from proposed allowable catches in relation to scientific recommendations.

Finally, Macho et al. (2013) investigate the key role of *Barefoot Fisheries Advisors* (BFA) in the successful transformation of the Galician (NW Spain) *S-fisheries* (small-scale and spatially structured fisheries targeting sedentary resources with artisanal gears, sensu Orensanz et al. 2005). The authors analyze the historical

development and evolution of roles of this novel and stimulating actor in fisheries management, who acts as knowledge collector and translator between stakeholders. The results show that BFA model allows (i) the provision of good quality and organized fisheries data and (ii) the link between fishers, managers, and scientists building this way robust social capital. Weak points of the BFA model and future perspectives are also discussed. The relevance of this work is highlighted by the lack in the literature, despite of its need, of simpler assessment and management procedures for providing scientific advice for sustainable small-scale fisheries management.

Acknowledgments We wish to thank all authors and reviewers for their valuable contributions. We also appreciate the support of Bo Söderström, Editor-in-Chief of *AMBIO*, who kindly assisted us during the publication process of this Special Issue. SV was funded by Campus do Mar-International Campus of Excellence and the Norwegian Research Council.

REFERENCES

- Abunge, D., S. Coulthard, and T. Daw. 2013. Connecting marine ecosystem services to human wellbeing: Insights from participatory wellbeing assessment in Kenya. *AMBIO*. doi:[10.1007/s13280-013-0456-9](https://doi.org/10.1007/s13280-013-0456-9).
- Anderies, J.M., M.A. Janssen, and E. Ostrom. 2004. A framework to analyze robustness of social–ecological systems from an institutional perspective. *Ecology and Society* 9: 18.
- Armstrong, C. 2007. A note on the ecological–economic modelling of marine reserves in fisheries. *Ecological Economics* 62: 242–250.
- Bené, C., R. Lawton, and E.H. Allison. 2010. Trade matters in the fight against poverty: Narratives, perceptions, and (lack of) evidence in the case of fish trade in Africa. *World Development* 38: 933–954.
- Da Rocha, J.M., R. Trelles-González, and S. Villasante. 2013. Credible enforcement policies under illegal fishing: Does individual transferable quotas induce to reduce the gap between approved and proposed allowable catches? *AMBIO*. doi:[10.1007/s13280-013-0459-6](https://doi.org/10.1007/s13280-013-0459-6).
- Fröcklin, S., M. de la Torre-Castro, M. Lindström, and J. Jiddawi. 2013. Fish traders as key actors in fisheries: Gender and adaptive management. *AMBIO*. doi:[10.1007/s13280-013-0451-1](https://doi.org/10.1007/s13280-013-0451-1).
- Gelcich, S., F. Amar, A. Valdebenito, J.C. Castilla, C. Godoy, M. Fernandez, and D. Biggs. 2013. Financing marine protected areas through visitor fees: Insights from tourists willingness to pay in Chile. *AMBIO*. doi:[10.1007/s13280-013-0453-z](https://doi.org/10.1007/s13280-013-0453-z).
- Hadjimichael, M., A. Delaney, M. Kaiser, and G. Edwards-Jones. 2013. How resilient are Europe's inshore fishing communities to change: Differences between the north and the south. *AMBIO*. doi:[10.1007/s13280-013-0458-7](https://doi.org/10.1007/s13280-013-0458-7).
- Kleisner, K., C. Longo, M. Coll, B.S. Halpern, D. Hardy, S.K. Katona, F. Le Manach, D. Pauly, et al. 2013. Exploring patterns of seafood provision revealed in the global Ocean Health Index. *AMBIO*. doi:[10.1007/s13280-013-0447-x](https://doi.org/10.1007/s13280-013-0447-x).
- Lopes, P., R. Silvano, and V. Nora. 2013. Transboundary socio-ecological effects of a marine protected area in the southwest Atlantic. *AMBIO*. doi:[10.1007/s13280-013-0452-0](https://doi.org/10.1007/s13280-013-0452-0).
- Macho, G., I. Naya, J. Freire, S. Villasante, and J. Molares. 2013. The key role of the *Barefoot Fisheries Advisors* in the co-managed TURF System of Galicia (NW Spain). *AMBIO*. doi:[10.1007/s13280-013-0460-0](https://doi.org/10.1007/s13280-013-0460-0).
- Moreno-Sánchez, R.D.P., and J. Maldonado. 2013. Adaptive capacity of fishing communities at marine protected areas: A case study from the Colombian pacific. *AMBIO*. doi:[10.1007/s13280-013-0454-y](https://doi.org/10.1007/s13280-013-0454-y).
- Orensanz, J.M., A. Parma, G. Jerez, N. Barahona, M. Montecinos, and I. Elias. 2005. What are the key elements for the sustainability of “S-fisheries”? Insights from South America. *Bulletin of Marine Science* 76(2): 527–556.
- Outeiro, L., and S. Villasante. 2013. Linking salmon aquaculture synergies and trade-offs on ecosystem services to human well-being constituents. *AMBIO*. doi:[10.1007/s13280-013-0457-8](https://doi.org/10.1007/s13280-013-0457-8).
- Vásquez-Lavín, F., J. Simon, and X. Paz-Lerdón. 2013. Determining the feasibility of establishing new multiple-use marine protected areas in Chile. *AMBIO*. doi:[10.1007/s13280-013-0455-x](https://doi.org/10.1007/s13280-013-0455-x).
- Villasante, S., D. Rodríguez-González, M. Antelo, S. Rivero-Rodríguez, J.A. de Santiago, and G. Macho. 2013a. All fish for China? *AMBIO*. doi:[10.1007/s13280-013-0448-9](https://doi.org/10.1007/s13280-013-0448-9).
- Villasante, S., D. Rodríguez-González, M. Antelo, S. Rivero-Rodríguez, and J. Lebrancón Nieto. 2013b. Why are prices in wild catch and aquaculture industries so different? *AMBIO*. doi:[10.1007/s13280-013-0449-8](https://doi.org/10.1007/s13280-013-0449-8).

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