



# Applying an ecosystem service approach to unravel links between ecosystems and society in the coast of central Chile



Silvia de Juan <sup>a,\*</sup>, Stefan Gelcich <sup>a,b</sup>, Andres Ospina-Alvarez <sup>a</sup>, Alejandro Perez-Matus <sup>a,c</sup>, Miriam Fernandez <sup>a</sup>

<sup>a</sup> Center for Marine Conservation, Departamento de Ecología, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile, Chile

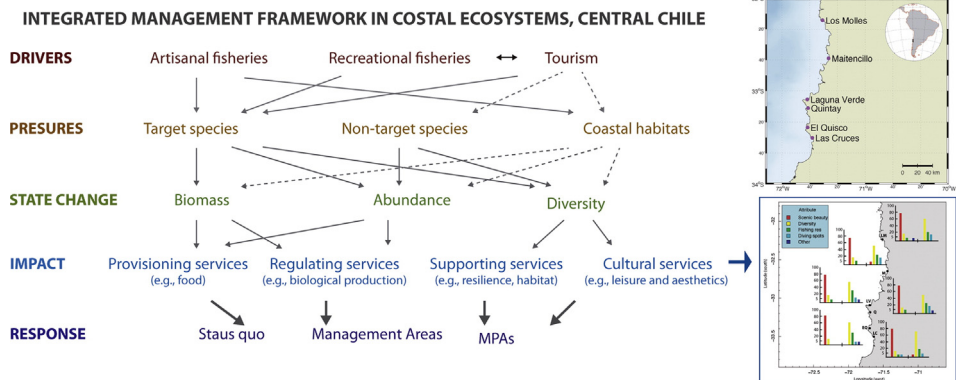
<sup>b</sup> Center of Applied Ecology and Sustainability (CAPES), Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile, Chile

<sup>c</sup> Subtidal Ecology Laboratory, Estación Costera de Investigaciones Marinas, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile, Chile

## HIGHLIGHTS

- The provision of ecosystem services was assessed in the central coast of Chile.
- The demand for services was elicited by questionnaires to fishermen and tourists.
- Uses could cause a state change of ecosystems, implying impoverished services.
- A DPSIR framework illustrated the interactions between society and ecosystems.
- This work improved our knowledge on links between uses and values in the study area.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Ecosystem-based management implies understanding feedbacks between ecosystems and society. Such understanding can be approached with the Drivers–Pressures–State change–Impacts–Response framework (DPSIR), incorporating stakeholders' preferences for ecosystem services to assess impacts on society. This framework was adapted to six locations in the central coast of Chile, where artisanal fisheries coexist with an increasing influx of tourists, and a set of fisheries management areas alternate with open access areas and a no-take Marine Protected Area (MPA). The ecosystem services in the study area were quantified using biomass and species richness in intertidal and subtidal areas as biological indicators. The demand for ecosystem services was elicited by interviews to the principal groups of users. Our results evidenced decreasing landings and a negative perception of fishermen on temporal trends of catches. The occurrence of recreational fishing was negligible, although the consumption of seafood by tourists was relatively high. Nevertheless, the consumption of organisms associated to the study system was low, which could be linked, amongst other factors, to decreasing catches. The comparison of biological indicators between management regimens provided variable results, but a positive effect of management areas and the MPA on some of the metrics was observed. The prioritising of ecosystem attributes by tourists was highly homogenous across the six locations, with "scenic beauty" consistently selected as the preferred attribute, followed by "diversity". The DPSIR framework illustrated the complex interactions existing in these locations, with weak linkages between society's priorities, existing management objectives and the state of biological communities. Overall, this work improved our knowledge on relations between components of

\* Corresponding author.

E-mail address: [sjmohan@bio.puc.cl](mailto:sjmohan@bio.puc.cl) (S. de Juan).

coastal areas in central Chile, of paramount importance to advance towards an ecosystem-based management in the area.

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## 1. Introduction

The current global scenario of decreasing biodiversity and habitat degradation (Worm et al., 2006) demands the adoption of comprehensive approaches to the management of human activities (Leslie and McLeod, 2007). Ecosystem-based management aims to meet the growing human needs for natural resources, while ensuring the conservation of biodiversity (Levin et al., 2009). To achieve this goal, managers must consider the interactions between different groups of users, and between uses and the environment (Leslie and McLeod, 2007; Granek et al., 2010). Ecosystem services have been defined as the attributes of ecosystems that provide benefits to society and improve human well being (e.g., food and material, recreational space, cognitive values) (MEA, 2005; Beaumont et al., 2007; Granek et al. 2010). Over the past years, many ecosystem-based management plans have incorporated the social perception of ecosystems, often through the concept of ecosystem services (Blasiak et al., 2014; Díaz et al., 2015). However, we still have a limited understanding on how the demand for services by society might compromise the sustainable use of ecosystems.

A common approach that could be broadly applied is needed in order to achieve ecosystem-based management goals. This approach could be achieved by standardising the multiple concepts embedded within the ecosystem-based management and integrating its multiple scales (Arkema et al., 2006; Carpenter and Folke, 2006). The Drivers–Pressures–State change–Impact–Response framework (DPSIR) was adapted from the Pressure–State change–Response framework launched by the Organisation for Economic Cooperation and Development and has been proposed as a system-based approach that captures the key feedbacks between society and ecosystems (Elliott, 2002; Muntadas et al., 2015). The DPSIR describes a framework for assessing causes, consequences and responses to ecosystem change in a holistic way (Atkins et al., 2011). It links pressures created by human demand for natural resources, such as food or recreational space, with the state change of ecosystems that ultimately requires a response by society in order to ensure the supply to future demands. This framework can be considered as a philosophical context for structuring and communicating relevant actions to stakeholders (Atkins et al. 2011).

In coastal areas, there is high economic and cultural dependency of human groups on marine ecosystems (MEA, 2005; Leslie and McLeod, 2007). However, in order to disentangle the multiple links within a socio-ecological system in coastal areas, a first and essential step is the identification of ecosystem services provided by biological communities and the use and perception of these services by society. The aim of the present work was to understand these links between coastal ecosystems and society. The study encompassed a set of coastal locations in central Chile, along a coast characterised by rocky reefs and kelp forests in one of the most productive marine ecosystems of the world (Wieters et al., 2003). The coast of Chile extends for over 4000 km with many human communities scattered throughout this area, benefiting from its high productivity and also increasing the demand for recreational space (Godoy et al., 2010; Cárcamo et al., 2014). Particularly in the central coast, most fisher villages receive a large influx of visitors in summer and weekends, since it is easily accessed from the country capital, Santiago. The increasing touristic demand might represent an additional pressure on coastal ecosystems that are already impacted by fishing activities. Tourists might impose a pressure on ecosystems directly by recreational use and indirectly by demand for seafood products or increased pollution (Hall, 2001). Moreover, tourists might degrade coastal habitats by demand for space and by trample on or collection of intertidal fauna (Davenport and Davenport, 2006).

The first objective of the study was to identify the ecosystem services and their demand in the study locations. Ecosystem services were quantified through measures of biomass, abundance and diversity of fish and invertebrates. Kelp forests might provide additional services like carbon storage or disturbance prevention (MEA, 2005; Palumbi et al., 2009; Duarte et al., 2013), but these services were not considered, as related functions have not been measured directly within the study area (but see approximations done by Vásquez et al., 2014). The use and perception of the coastal ecosystem by the main groups of users (tourists and fishermen) was analysed to assess the demand for ecosystem services in these areas. The second objective aimed to identify relationships between the provision and demand of ecosystem services by the adaptation of a DPSIR framework to our study area (Fig. 1). We adopted this integrated framework aiming to illustrate the complex interactions existing in the study locations, where understanding the implications of the demand for ecosystem services is essential for the ecosystem-based management of coastal areas.

## 2. Methods

### 2.1. Research setting

The study encompassed six coastal locations from central Chile (ca. 28°S–33°S): Las Cruces, El Quisco, Quintay, Laguna Verde, Maitencillo and Los Molles (Fig. 2). The tourism sector in these locations is principally domestic and of individual nature, as most visitants travel from nearby cities to spend holidays in a second-home or in a rented house. However, the tourist influx is high. Despite official records on visitants per year were not available in most locations, for example, Maitencillo exhibits an approximate fixed population of 2,000 inhabitants, but receives roughly 12,000 tourists per year.

Coastal fisheries include divers and coastal gatherers that target subtidal and intertidal benthic invertebrates and reef fish principally from rocky reefs, often dominated by kelp forests. Over past years, harvesting of kelp has increased (the species with highest yield pertain to the genera *Lessonia* spp.). The exploitation of benthic resources is regulated under two contrasting strategies. On one side, Territorial Use Right in Fisheries regime (locally known as “Management Areas for the Exploitation of Benthic Resources”), that assigned portions of the seabed to fishermen associations that have the exclusive right to exploit economically important benthic resources inside these areas (Gelcich et al., 2010). On the other side, outside the fisheries management areas there is an open access regimen for all benthic resources of the artisanal fisheries, with the exception of the highly valued gastropod *Concholepas concholepas* (common name: “loco”) that is banned in open access areas.

### 2.2. The demand for ecosystem services in the coast of central Chile

The demand for ecosystem services was assessed by face-to-face questionnaires in the six locations during the austral summer–autumn 2014. Questionnaires targeted the principal groups of users in these areas: fishermen and tourists. In each location, we conducted 100 questionnaires that targeted tourists (an overall of 602 questionnaires) and 15–20 questionnaires targeting artisanal fishermen (an overall of 99 questionnaires). Additionally, 50 questionnaires per location targeted permanent residents to complement information on the most frequent activities. The individuals being interviewed were randomly selected. The lower sample size for permanent residents and artisanal fisheries is linked to a small effective population size of some villages. Survey

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