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Evaluation of the effects on rockfish and kelp artisanal fisheries of the proposed Mejillones Peninsula marine protected area (northern Chile, SE Pacific coast)

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ABSTRACT

1 One shortcoming of marine protected areas (MPA) implementation is the potential for unintended consequences, such as fisheries effort displacement, that cause negative economic and social effects for fishermen and undermine social support for MPA implementation efforts.
2 The objective of this work is to analyse the effects of a proposed MPA system on fisheries in a biodiversity conservation priority site in northern Chile using a spatial dynamic modelling approach and incorporating ecological, social and economic criteria.
3 We developed an Ecospace model representing the ecological benthic subsystems dominated by kelp beds off the Mejillones Peninsula, Chile. We compared changes in fisheries indicators and the spatial distribution of effort among a no-MPA baseline scenario and four scenarios using proposed MPA core and buffer zones with high or low dispersal rates for the species in the model.
4 An overlay analysis was performed to identify which zones and users of the fishing grounds would be affected by the proposed MPA system and to what degree.
5 We found a high degree of overlap of the proposed MPA site with fishing grounds of high economic importance and with a fishing ground where women are allowed to work, this can cause significant displacement of women that have no alternative livelihood, with possible undesired social impacts on the fishing community.
6 Results from the kelp forest spatial food web model reveals that the biomass build-up of fished species is sensitive to dispersal rates, especially in scenarios with small reserves. A general pattern of fishing effort reallocation at the border of individual MPAs and open areas closer to the port was observed. Fisheries indicators show negative effects for both MPA scenarios, with undesirable changes in catch and profits for rockfish and kelp exploitation.
7 Our results suggest that implementation of the MPA proposal for the Mejillones Peninsula could generate negative consequences for the fishing community of Constitución cove. The inclusion of fisheries management objectives along with biodiversity conservation in the planning process of the Mejillones Peninsula MPA system may help to address putative negative effects on fisheries and may allow for the creation of support for future MPAs from the fishermen community.

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1. Introduction

In light of the current threats to the marine environment, an ecosystem approach for the management of marine resources has been proposed, which involves incorporating the protection of ecosystem processes and components that generate structure and function and in turn deliver ecosystem goods and services to humans (Arkema et al., 2006; Pikitch et al., 2004). Marine protected areas (MPAs) are regarded as suitable tools under this approach, especially where human activities threatening marine ecosystems should be excluded or controlled (Hughes et al., 2005; Lubchenco et al., 2003a,b).

The marine protected areas for the biodiversity conservation program is considered appropriate and effective in light of growing evidence in support of conservation benefits as a whole (Halpern and Warner, 2002; Lester et al., 2009). However, the implementation of marine reserves where fishing is prohibited or restricted is still controversial, particularly among fishermen, despite the amount of evidence in favour of beneficial effects from these no-take MPAs (Gell and Roberts, 2003; Roberts et al., 2005; Sladek-Nowlis and Friedlander, 2005; Viteri and Chávez, 2007).

Stakeholders involved in the process of implementing a system of marine protected areas usually have different and often divergent values, interests and objectives (Halpern and Warner, 2003; Mangi and Austen, 2008; Pomeroy and Douvere, 2008). If this type of social context is not incorporated into the planning process, it is possible that the whole process and the restrictions implemented, primarily access and resource extraction restrictions, may be questioned by stakeholders and/or cause negative social and economic effects (Agardy et al., 2011; Helvey, 2004; Mascia et al., 2010; Stewart and Possingham, 2005). This situation may lead to low levels of compliance with management measures, such as no take zones, endangering the effectiveness of the MPA system (Faasen and Watts, 2007; McClanahan, 1999; Viteri and Chávez, 2007).

In the case of Chile, biodiversity conservation has been the main objective of the first MPAs implemented, and fisheries management is absent or appears as a secondary objective (Fernandez and Castilla, 2005). However, most marine conservation priority sites identified by the National Environmental Agency are inhabited by artisanal fishermen communities, which have territorial user rights for marine resources and/or traditional fishing grounds in the same area where MPAs should be located (Tognelli et al., 2009, 2005). In addition, a study that evaluates artisanal fishermen's perceptions of the no-take area component of the MPA plan and their willingness to participate in the administration and management of the protected area found that artisanal fishermen are interested in participating but feel that the planning process is essentially dominated by biodiversity conservation objectives with weak or no concern for their interests (Gelcich et. al., 2009).

Along the north-central Chilean coast, the subtidal kelps species *Macrocystis pyrifera* and *Lessonia trabeculata* are heavily exploited by artisanal fishers communities for alginate production and as food for abalone aquaculture (Vásquez et al., 2012). In this fishery men and women participate, although women are not allowed, traditionally, to participate in kelp harvesting from boats, as a result they work gathering beached kelp fronds along the coast, this is not an informal or illegal practice since gatherers must register and report landings to the Fisheries service, also they work in other activities like drying and packing the harvested kelp. The absence of standardized harvesting methods has made regulation difficult, and complete removal of individuals from a population is the method currently used (Ortiz, 2010). This, in combination with the impacts ofoceanographic disturbances has resulted in some kelp populations being considerably reduced. (Borras-Chavez et al., 2012). Recently, a multiple use marine protected area proposal was commissioned by the Ministry of Environment (Hudson et al., 2009, 2008; Ulloa et al., 2013) for the Peninsula de Mejillones to protect marine and terrestrial biodiversity along coastal areas; it included subtidal kelp ecosystems exploited by artisanal fishers that can be impacted by the implementation of the MPA (Pérez-Matus et al., 2007; Villegas et al., 2007). In light of this situation, we believe that it is relevant to assess the putative negative and positive consequences of MPA proposals for fishermen communities before they are fully implemented.

Walters et al. (1999) developed a model framework called Ecospace, which allows spatial dynamic modelling based on trophic mass-balanced models using Ecopath (Christensen and Pauly, 1992) and dynamic simulations by Ecosim (Walters et al., 1997). Ecospace has been used to evaluate the effects of marine protected areas and territorial user rights on fisheries and ecosystem properties in Chile and other parts of the world (Fousay et al., 2012; Le Quesne et al., 2008; Ortiz, 2010, 2008 Ortiz and Wolff, 2002; Pitcher, 2002 Varkey et al., 2012). Also, there are in the literature many examples of work describing the social and economic impacts of MPAs on fishing communities, and the use of decision-support tools like MARXAN to examine outcomes of MPA design on fisheries value (Mascia et al., 2010; Klein et al., 2010, 2008a). While this approach is very efficient in producing MPA configurations that minimise fisheries value loss without compromising conservation goals, the MARXAN algorithm uses information on spatial distribution of conservation features (species, habitats, communities, etc.) and fishing effort that represents the situation at the time when it was collected (Klein et al., 2008b) in this sense it is a static representation of the system under analysis. Since MARXAN is not a model, it cannot be used to predict fisheries responses such as fishing effort redistribution in space after MPA implementation. The space-time dynamical modelling approach we used evaluates the effects of MPA configurations on fisheries based on the responses, triggered by the MPA implementation, in ecological and fisheries processes, represented by variations in space and time of species biomass and fishing effort, taking account of the effects of connectivity, habitat change, or any other environmental driver that has an influence on species or functional group spatial distribution (Christensen et al., 2008, 2014a). MPA impacts on fisheries can be characterized using ecological and socio-economic criteria, changes in biomass for target resources and other species of ecological importance such as keystone or habitat forming species and trophic cascades has been used as ecological criteria (Guidetti and Sala, 2007 Watson et al., 2000). Economic and social impacts has been characterized using criteria such as changes in catch value, profit, fisheries related jobs and fishing effort displacement (Forcada et al., 2010; Smith and Wilen, 2003; Stevenson et al., 2013). Also, potential conflicts and the risk of negative effects on fishing communities might arise in part due to the broad scale and poor thematic quality of spatial data on human uses of the marine environment incorporated in the MPA design process (Richardson et al., 2006; Scholz et al., 2011), we incorporate in our analysis additional spatially explicit information of the different activities and users of the seascape to evaluate potential zones and users that could be affected by the proposed MPA system.

The main objective of this work is to construct a multi-species trophic model that includes spatial heterogeneity (i.e., varying habitats) of the benthic subsystems in the Mejillones Peninsula. The spatial model will allow us to assess the effects of an MPA system proposal on fisheries at a biodiversity conservation priority site in northern Chile (Mejillones Peninsula) while incorporating ecological, social and economic criteria.