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Mapping ecosystem services for marine spatial planning: Recreation opportunities in Sub-Antarctic Chile

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ABSTRACT

The ecosystem services approach has increasingly emerged as a core requirement of ecosystem-based management of the marine space. In this context, explicit quantification and mapping of ecosystem services is considered key. This research proposes a methodological framework that combines Geographic Information Systems and participatory techniques to map the ecosystem service of recreation opportunities, provided by coastal and marine ecosystems. Attributes selected to represent the ecosystem service were scenic beauty, unique natural resources, accessibility, cultural sites and tourism use aptitude. High values of the indicator concentrated on areas that combined the presence of unique marine fauna (e.g. Southern Elephant Seal, *Mirounga leonina*), terrestrial and marine routs, and areas of high scenic beauty, associated to the presence of glaciers. These areas corresponded to the southern part of Almirantazgo Sound, the northern part of Navarino Island on the coast of the Beagle Channel, and to areas surrounding Wulaia fishermen's cove. Zones showing highest values of the indicator 81–100) comprised 0.89% of the study area and a small proportion of them coincided with areas of aptitude for aquaculture, which represents potential use conflicts, as long as aquaculture concessions remain operative. In turn, the areas of lowest values 0–20) were located offshore in open sea, and comprised 0.49% of the study area. Overall, the methodology demonstrated the capacity to identify potential recreation areas to inform regional decision making regarding marine use planning.

1. Introduction

Throughout the world, people depend deeply on the oceans and coasts and the resources they provide, for livelihood survival and wellbeing [1]. Global estimates indicate that the world's ocean and coastal biomes provide as much as two thirds of the ecosystem services that make up the planet's natural capital [1,2]. At the same time, very little is known about them. “Ocean and costal ecosystems suffer-perhaps more than any other ecosystem-from both knowledge and governance deficits” [2]. They are increasingly threatened by human activities such as over fishing, marine pollution, marine habitat change, climate change, invasion of non-native species, and other impacts of a rapidly growing human population [2–4].

These multiple impacts can impair the structure and functioning of these ecosystems, which in turn may negatively affect their capacity to generate ecosystem services —the components of nature directly used, consumed and/or enjoyed to yield human wellbeing [5]. In this context of increased and competing pressures, the ecosystem service approach (ESA) to biodiversity conservation goes beyond how people affect ecosystems, and includes how society depends on, benefits from, and is affected by an ecosystem [1,6]. For this reason, the scientific community and policy makers have increasingly advocated for the use of ESA as a management tool [7,8]. UNEP-WCMC [4] states that “the principal means for communicating the consequences of ecological change for human wellbeing is to document the impacts on ecosystem services”.

Application of ESA has been recognized as a core requirement for implementing ecosystem-based management for marine and coastal environments, as it facilitates protection of key ecosystem services and offers improved evaluation of marine resource uses, impacts and tradeoffs based on human wellbeing [9,10].

In operational terms, ESA is a problem solving framework, which commences with the identification of a management/policy problem, in which ecosystem services provision and social, economic and politico-cultural contexts are delineated and defined in terms of scale. Chosen services are then modelled, mapped and valued. Lastly, management

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choices and their opportunity costs are explored via scenarios of future states of the world and/or policy interventions [11]. Specifically, the spatial representation (mapping) of ecosystem services has been recognized as a key undertaking for mainstreaming ESA in policy and decision making [12–14].

Whereas increasing contributions have been made to the literature for terrestrial ecosystems, the mapping of coastal and marine ecosystem services remains limited. Only few mapping studies can be found [15–19] despite recognition of the importance of spatial representation of ecosystem services in marine planning [18,20,21].

One of the most notorious ecosystem services provided by coastal and marine ecosystems is recreation opportunities, also called opportunities for recreation and ecotourism [1], classified as a cultural ecosystem service. For most cultural services, the distinction between the service itself and the benefit is challenging. In the case of recreation opportunities, combinations of recreation activities and settings jointly determine the recreational choices people make. All recreation settings can be described by their biophysical (e.g. singular landscape attributes), social (e.g. sense of solitude) and managing attributes (e.g. access to site), which together sustain a potential recreation opportunity. Recreation activities in turn represent the benefits, which are a combination of the ecosystem service and other forms of built capital [22,23].

Whereas in terrestrial ecosystems a series of indicators have been proposed to map recreation opportunities [24,25], in coastal and marine ecosystems very few studies can be found [16,18]. Additionally, indicators proposed for assessment are usually benefit indicators, such as number of visits per person per year, number of trips per person per year, number of hotel rooms [26] or number and quality of beaches [20], rather than flow indicators, as proposed here.

This research develops and applies a methodological framework that combines Geographic Information Systems and participatory techniques to map recreation opportunities provided by coastal and marine ecosystems.

This is particularly important in a study area such as the present that comprises a Biosphere Reserve and has been nominated as a world class tourist destination due to its remarkable natural features and pristine environments. In Chile, coastal and marine ecosystem services have been scarcely assessed and the few existing studies were conducted in refer to northern latitudes [18,27–31]. To the best of our knowledge, there are no studies conducted as far south as the Magallanes and Antarctic region.

2. Methods and data

2.1. Study area

The specific study area is found in the extreme southern tip of South America, within the Region of Magallanes and Chilean Antarctica (54°5′46.42" to 56° 9′2.85" south and 73°13'15" and 66°2′57.28" west) including part of the provinces of Tierra del Fuego, Magallanes and Antarctica (Fig. 1). Together, these comprise a terrestrial area of 19,225 km^2, fjord and channel area of 14,618 km^2, and open ocean area of 15,272 km^2. It is also the southernmost archipelagic and fjord territory in the world.

Geography is dominated by the Cordillera Darwin, whose ice field has given origin to the formation of the fjords and channels of the area since the last glacial period.

Until the arrival of European explorers and conquerors (16th century) this territory was inhabited by the Kaweshkar (or Alacalufes), Selk'nam (or Onas) and Yámana (or Yagan) peoples. Their decedents began to disappear in the following centuries, first because of contact with foreigners, but principally due to the expansion of commercial activity (livestock farming) and evangelization, taking place during the 19th and 20th centuries. This area acquires its importance from the 16th century because of the discovery of an interoceanic passage (Strait of Magellan), through which passed the ships sent by European colonists. In the 19th century, the expeditions that arrived to the area were mainly with exploration and extraction purposes. Mining and farming industries were set up that were to determine the population of the region [32]. Currently, the main economic activities in the provinces are concentrated in raising livestock, artisanship and industrial fishing [33].

The study area is subject to private and state administration, and the largest zone is the Cape Horn Indigenous Development Area, which is managed by the Indigenous Development National Corporation. This area includes all the Cape Horn Commune and has a surface area of 1,414,600 ha.

National Parks in this territory include Alberto de Agostini, Yendegaia and Cape Horn, all under administration by the National Forestry Corporation. Another small area destined to conservation is governed by the Ministry of National Holdings on Albatross Islet in Almirantazgo Sound. All the coastline, up to 80 m from the highest tide, is under the jurisdiction of the General Maritime Territory Direction from the Chilean Navy. Within the same space, the wild terrestrial and marine species are the responsibility of the Ministry of the Environment and the Agriculture and Livestock Service. Natural resources considered for fishing are overseen by the National Fishing and Aquaculture Service. There are also two private protected areas, namely Karukinka Natural Park, held by Wildlife Conservation Society (297,000 ha) in Tierra del Fuego, and Omora Ethnobotanical Park (1000 ha) that pertains to the Ministry of Public Holdings and is administered by the Omora Foundation.

Despite being an isolated territory, the marine and terrestrial ecosystems are defined as priority areas for tourism development, given they are endowed with unique features such as the marine fauna and flora, glaciers, fjord channel networks, sea and landscapes [34]. Most of these recreation opportunities are untapped and difficult to access due to inadequate infrastructure and support services, thereby presenting a challenge to the development of tourism in geographically isolated areas.

2.2. Indicator development steps

The development of the GIS based protocol followed four steps, as described below.

2.2.1. Step 1 Selection of attributes and spatial variables

Ecosystem services flows are sustained by ecological and landscape functions and attributes that need to be identified for the construction of indicators. To select these attributes, prior works were taking as referent about the provision of recreation opportunities in terrestrial ecosystems [24]. Expert criteria were also used to incorporate or modify attributes unique to the marine ecosystems. Selected attributes were: accessibility, tourism use aptitude, unique natural resources, cultural sites and scenic beauty. Different variables were selected that integrated the spatial dimension of each attribute (Table 1). This selection was carried out based on bibliographic references from prior studies on recreation opportunities and the availability of spatial databases from secondary sources. For the accessibility attribute, terrestrial, aerial and marine routes were used. The attribute of tourism use aptitude refers to the capacity of different land covers to support specific recreational activities. To build this attribute, recreational activities were identified that could be carried out on each land cover identified in the Native Chilean Vegetation Resource Map for the Region of Magallanes and Chilean Antarctica [35] (see Table 2). Also included were cover areas containing fjords and open ocean, that were not considered in the Resource Map. Unique natural resources comprised information about the presence of marine fauna, forests of high conservation interest, and protected areas. Cultural sites were represented by ancestral routes, archeological sites, and ancestral lands. Finally, scenic beauty was represented by the presence of glaciers and