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Current state of goods, services and governance of the Humboldt Current Large Marine Ecosystem in the context of climate change

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ABSTRACT

The Peru-Chile GEF-UNDP-Humboldt Current Large Marine Ecosystem Project successfully completed its first five-year phase. It included the delivery of ten thematic reports (TR), a Causal Chain Analysis (CCA), Ecosystem Diagnostic Analyses (EDA)(one each for Chile and Peru), a Transboundary Diagnostic Analysis (TDA) and a Strategic Action Program (SAP). The transboundary problems affecting the state of goods and services provided by the Humboldt Current Large Marine Ecosystem (HCLME) are: (1) non optimal use of fishing resources with socio-economic consequences; (2) anthropogenic disturbance of marine habitats after an increase in pollution levels within the HCLME; and (3) high incidental by-catch and associated fauna destruction and discards as a common problem for the two countries. Governance aspects developed during the past five years (2011-16) included, a "bottom-up" process in Peru and Chile linked to the establishment of new fishing and aquaculture acts, Marine Protected Areas and territorial use rights for artisanal fisheries, new methods for fish stock assessment, and ecolabelling of fisheries, among others. Management plans have been designed for pilot sites: the Juan Fernandez Archipelago in Chile; and Lobos de Tierra Island, Ballestas Islands and San Juan cape in Peru.

A first Total Economic Value calculation of the goods and services provided by the HCLME in 2015 indicates a delivery of US$19.45 billion per annum. This value comprises 58% from Chile (US$ 11.28 billion) and 42% from Peru (US$ 8.17 billion). Additionally, the area of direct influence of the Humboldt Current System generates 77% (US$ 14.97 billion) of the value produced by the HCLME, where the tropical area of Peru and the southern area of Chile added 2% (US$ 0.45 billion) and 21% (US$ 4.03 billion), respectively.

Possible scenarios of climate change in the HCLME were focused on the changes of biogeochemical alterations and forcing on the productivity and abundance-distribution of key species. Currently, high ocean productivity is an expression of the relatively high biomass of pelagic fish like anchovy, pacific jack mackerel and sardine, also other fishing resources like demersal fish (hake), cephalopod molluscs (squid), crustaceans (shrimp) have important contributions. Nevertheless, a deeper analysis of the impacts of climate on the fisheries and coastal areas of the HCLME is needed.

1. Introduction

The Humboldt Current Large Marine Ecosystem (HCLME), like all Eastern Boundary Upwelling Systems (EBUS), presents the main characteristics of strong upwelling and a high primary and secondary production including pelagic species (Barber and Chavez,

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1983; Bakun and Broad, 2003). In the case of the HCLME the constant southerly winds activate the productivity via continuous coastal upwelling in the northern sector (seasonal in the south) derived from Ekman transport causing westward surface water movements (Arntz and Fahrbach, 1996), a characteristic that distinguishes it from other Large Marine Ecosystems (LME).

However climate change is a significant threat to the productivity of the HCLME; Peru and Chile are vulnerable countries regarding climate change (Inostroza and Zavala, 2015; Allison et al., 2009), their economic growth depends on industries sensitive to the climate (fishery, agriculture, forestry and tourism), and where limited financial resources, infrastructure and social capabilities exist thereby restricting adaptation efforts.

The impacts of climate change include: (i) ocean acidification; (ii) heating of the ocean surface; (iii) changes in wind strength, upwelling and decreasing pelagic fish recruitment; (iv)changes in ocean currents; and (v) increases in the frequency of ENSO events, among others (Inostroza and Zavala, 2015; Allison et al., 2009).

Evidence of past climate variations also characterize the HCLME and they are described in its sediments (Siffedine et al., 2008). Several studies have shown an intensification of upwelling and primary production since the second half of the 19th century (e.g. Vargas et al., 2004). The HCLME now has more acidic waters because the concentration of carbon dioxide increases due to sinking organic matter from biological production being decomposed by bacteria (Fernand and Brewer, 2008). The 'natural CO_2' in addition to additions of anthropogenic origin, contribute to the lower pH in the HCLME area (Serra et al., 2012).

In Chile, between 1901 and 2005 Sea Surface Temperature (SST) warming ranging from 0.2 to 1.1 °C has been observed in the northern region of the interior austral zone while in the central and southern areas there is a cooling of - 0.2 to - 0.5 °C. There has also been a cooling of −0.2 °C per decade in the coastal area of north and central-south Chile (Inostroza and Zavala, 2015; Falvey and Garreaud, 2009). In Peru, there is a cooling trend in the central-south area, but an increase of SST for the northern region (Gutiérrez et al., 2011).

Both Chile and Peru are adopting mitigation and adaptation measures regarding climate change, most of them related to the conservation of natural resources and biodiversity (Inostroza and Zavala, 2015). In this regard, this article presents a description of the current state of goods and services delivery and associated governance of the HCLME in the context of Climate Change.

2. High variability of the HCLME

The HCLME is subject to natural climatic fluctuations in various spatio-temporal scales, with extreme events being the El Niño (warm) and La Niña (cold) (Chavez et al., 2003; Chaigneau et al., 2013) anomalies. Events of shorter duration such as Kelvin wave propagation are also frequent (Dewitte et al., 2008; Bertrand et al., 2008). Kelvin waves induce the advection of warm equatorial water masses even during the austral winter (Johnson and McPhaden, 1993). Reciprocally to the Kelvin waves, a dynamic process is initiated in the coastal area between coastal and subtropical waters. These are the Rossby waves, which propagate westward, cooling the surface of the equatorial Pacific Ocean (Dewitte et al., 2008).

The HCLME is also characterized by a complex dynamic superimposition of surface and sub-surface flows of opposite direction of meso and sub-mesoscale (Dewitte et al., 2008). This turbulence includes the formation of meanders (eddies) of cyclonic and anticyclonic rotation (Chaigneau et al., 2008) linked to convergent and divergent processes of primary and secondary productivity, both in the coastal and high seas areas. These dynamics control the distribution and abundance of fish stocks (Hormazábal et al., 2004) (Fig. 1).

Events of longer duration such as El Niño or La Niña, or more prolonged environmental regimes that can last several decades determine fundamental changes in the functioning of the ecosystem (Thiel et al., 2007). A vast proportion of the HCLME is currently uncoupled with global warming but this trend will change in the future (Brochier et al., 2013) impacting on the overall productivity of the system (Gutiérrez et al., 2016).

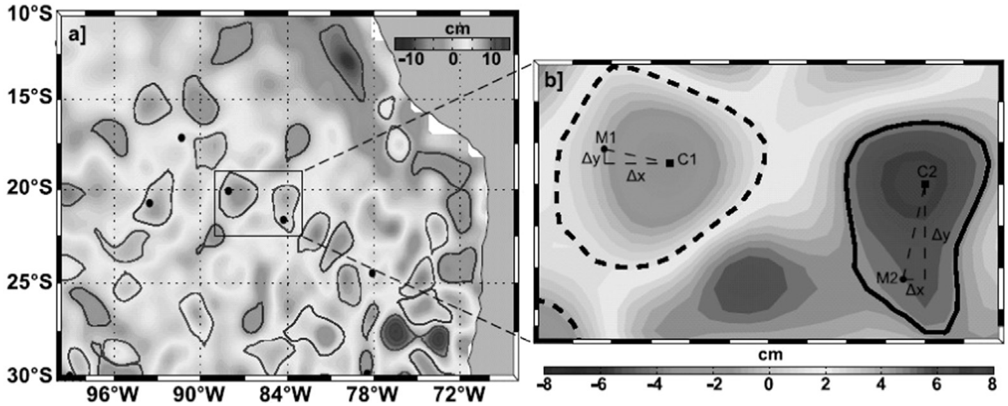

Fig. 1. Illustrative example of the detection and classification algorithm of anticyclonic and cyclonic eddies off Chile based on Argo profiles. (a) the darker areas correspond to the higher anomalies of mid sea level (in cm), polygons indicate the cyclonic or anticyclone eddies. (b) illustration of the positions of the drifters (floats M1 and M2) in relation to the corresponding centres of each eddy (C1 and C2). Anticyclonic eddies (enclosed by a continuous line) are generally related to dynamic processes of particle concentration, and the cyclone eddies (enclosed by a dotted line) are processes linked to dispersion.
Source: Chaigneau et al. (2011).