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Productivity and Sustainable Management of the Humboldt Current Large Marine Ecosystem under climate change

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ABSTRACT

The Humboldt Current Large Marine Ecosystem (HCLME) covers 95% of the southeast Pacific seaboard of which the area of influence from the Humboldt Current and associated upwelling areas in the Humboldt Current System (HCS) stretches from around 4° to 40° south. Global warming will likely affect marine circulation and land-atmosphere-ocean exchanges at the regional level, affecting the productivity and biodiversity patterns along the HCLME. The expected decrease of upwelling productivity in the HCS could be amplified by worldwide trends of oxygen depletion and lower pH. In addition, higher frequency of extreme climatic events, such as El Niño in a warmer ocean, might augment the risks for the recruitment success of anchovy and other short-lived fish resources, especially in the Northern HCLME. A range of non-climatic anthropogenic stressors also combines to reduce productivity and biomass yields. Transboundary Diagnostic Analysis (TDA) work has shown that overfishing and pollution are the main contributing factors in addition to the shared problem between Chile and Peru of high levels of fisheries bycatch and discards. An economic valuation of the HCLME and HCS has been finalized with an estimated annual delivery of around USD19.5 billion in goods and services. With many knowledge gaps this is evidently an underestimate but indicates which mitigating activities under a recently developed bi-national Strategic Action Programme (SAP) need to be prioritized. Fisheries landings are declining and demand for products is increasing. Improvement of ecosystem planning and management tools with value addition options for marine products is needed to adapt to climate change.

1. Introduction

The Humboldt Current Large Marine Ecosystem (HCLME) covers the area within 55° of latitude off Peru and Chile (3°23.57′ to 58°21.02′) and over 200 nautical miles offshore (Fig. 1). 65% of the HCLME extension corresponds to the Humboldt Current System (HCS), which is under the influence of seasonal or permanent coastal upwelling, from approximately 4 to 40° south.

Several features characterize the HCLME among similar ecosystems associated with Eastern Boundary Currents (EBCs: California, Canarias, Humboldt and Benguela). First, it extends closest to the equatorial line among the four systems. Second, it is the most exposed EBC system to the El Niño Southern Oscillation, which is the largest source of interannual climatic variability on the Earth. Third, it exhibits the highest fish productivity among the four EBC systems, notwithstanding primary

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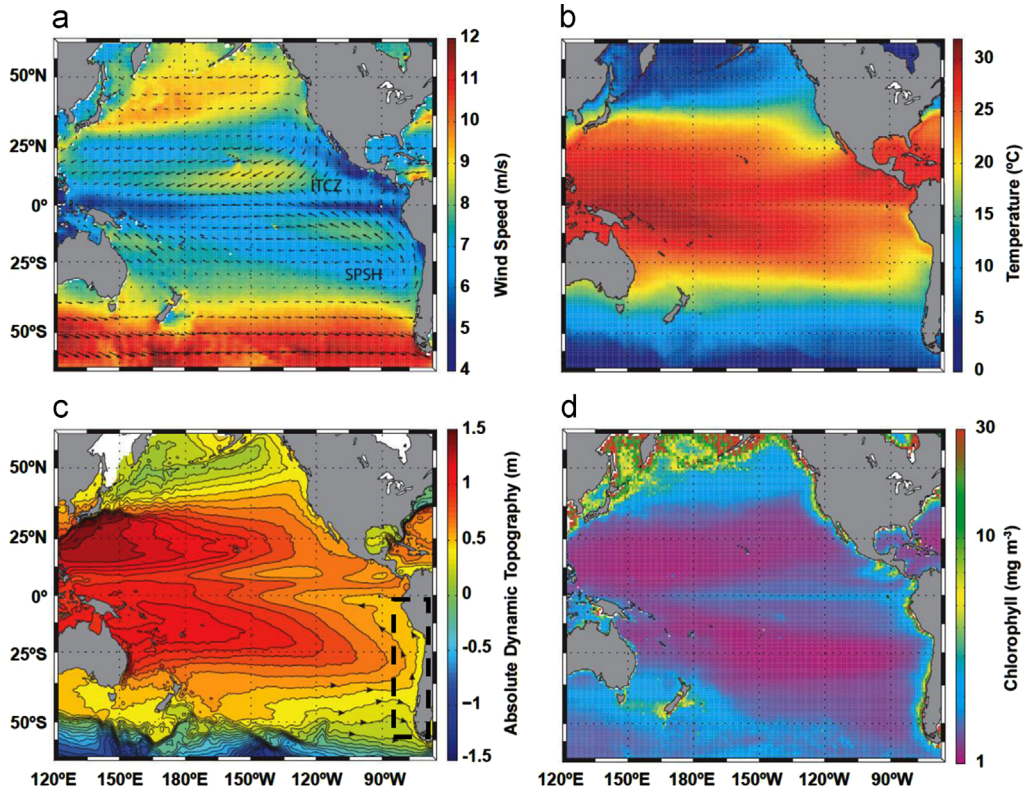

Fig. 1. The HCLME in the Pacific Ocean context. Annual mean distributions of the wind field (a); Sea surface temperature (b), dynamic topography and associated geostrophic currents (c), and surface Chlorophyll-a concentration (d). Sources: Quickscat (1999–2009), MODIS (1993–2010); AVISO (1993–2012); and Modis (2003–2010), respectively. The HCLME domain is shown in a dashed line envelope in (c).

productivity is in the same range as the primary productivity of the other systems. Fourth, it is associated with the presence of a shallow intense subsurface oxygen minimum layer that compresses the oxygenated epipelagic habitat to a few dozen meters.

Global warming is likely to alter the atmosphere–ocean–continent energy and matter exchanges, modifying the pressure gradients and alongshore and cross-shore wind fields along with marine currents, sea surface temperature (SST) and the thermal stratification, in addition to the intensity and spatio-temporal distribution of coastal upwelling. Global models predict the decrease of marine primary productivity and a significant loss of marine biodiversity, especially at the tropic and polar latitudes. On the other hand, the influx of anthropogenic CO_2 to the ocean and large-scale stratification are causing acidification and deoxygenation, which might trigger a cascade of biogeochemical and ecological changes in marine ecosystems. It is uncertain how these multiple stressors will impact on the productivity and biodiversity of the HCLME. A debate about the response of EBC upwelling ecosystems to global warming is ongoing with contradictory future scenarios (upwelling intensification vs weakening). In any case, physical and biogeochemical changes will likely affect the phenology, spatial distributions and species compositions of primary and secondary producers. Improving resiliency by reducing non-climatic hazards is the current challenge to ensure the adaptive sustainable management of this large marine ecosystem.

2. Setting the scene

The Humboldt Current (HC) or Peru Current is the large-scale offshore surface current that derives from the West Wind Drift (WWD) at around 40°S and flows northwards along the Pacific eastern seaboard as part of the Coriolis force induced South Pacific gyre (Fig. 1). The WWD also originates as a coastal poleward flow south at 45°S, the Cape Horn Current, which mixes the more saline waters with the fresher waters from the Chilean fjords. Off Central Chile the HC attains high speeds and it is relatively narrow and coastal; then it progressively moves away offshore on its northward path. Off Peru, the current mixes with eddy-like structures, until it joins the South Equatorial Current at 5–10°S (Strub et al., 1998). In general terms, the Humboldt Current System (HCS) extends up to 1000 km from the coasts of Chile and Peru, and it is composed of equatorward and poleward surface and subsurface currents (Fig. 2).

Large-scale forcing of the HCS dynamics is driven by the South Pacific Subtropical high-pressure cell (SPSH) and by the Equatorial ocean-atmosphere circulation. The SPSH-derived wind field induces the Ekman divergence nearshore and coastal