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Sub-regional ecosystem variability in the Canary Current upwelling

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ABSTRACT

The Canary Current upwelling ecosystem (CanC) constitutes one of the four main eastern boundary upwelling ecosystems (EBUEs) of the world, thus hosting high productivity and fisheries. Recent observations indicate that the CanC region as a whole has been experiencing a progressive warming and a decrease in productivity over the last decades. This overall trend is however not directly reflected in the fisheries of the region. Here we update recent results and previous reviews on the CanC, covering aspects from the physical environment to fish populations and fisheries on a range of time scales. We approach these topics, when possible, through a comparative exploration of the biogeographical characteristics of different sub-regions comprising this ecosystem. This review shows that variability in coastline configuration, shelf width, coastal upwelling, nutrient fertilization, productivity, or retentive vs. dispersive physical mechanisms, among other factors, may help explain sub-regional differences in fish distributions and abundances in the CanC. Nevertheless, the lack of systematic information on the regional variability of physical and biological processes hampers an integrated understanding of the relative contribution of natural vs. human-induced variability in the populations of at least small-pelagic fishes and their associated fisheries.

1. Introduction

The large marine ecosystem of the Canary Current (CanC), in its broadest sense, covers the latitudinal range 12–43°N (Fig. 1), although both northern and southern limits shift seasonally. Apart from the obvious geographical split at the Strait of Gibraltar, the CanC region is distinguished by its strong geographical diversity, which can determine the unique upwelling ecosystem response of different localities under similar annual and inter-annual forcing. In the recent past, several studies have focussed on general aspects of the CanC as a whole (Barton, 1998; Arístegui et al., 2006) or on the detailed nature of particular regions (Pelegrí et al., 2005; García-Lafuente and Ruiz, 2007; Hernández-León et al., 2007; Relvas et al., 2007). Here we review the structure and functioning of the ecosystem, covering aspects from the physical environment to living resources and their variability on a range of time scales, through a comparative exploration of the biogeographical characteristics of five different sub-regions (Table 1 and Fig. 1b).

Each sub-region has been defined in terms of factors such as its coastline orientation making it more or less susceptible to upwelling, the presence or absence of significant freshwater input from the coast, the existence of embayments that locally concentrate the effects of vertical circulation, the strength and seasonality of the forcing, or the dominant water mass. While it is possible to sub-divide further on the basis of ever-finer distinctions, the five sub-regions identified have clear differences in terms of circulation, physical environment and shelf dynamics. These have strong implications for their biogeochemistry, productivity, availability of suitable spawning grounds, larval survival, and fish populations, as will be discussed in the following sections.

The Atlantic Iberian sector may be separated into the *Galician* and *Portuguese* (west coast) sub-regions, both of which are strongly influenced by freshwater outflow, increasing northwards. Although these sub-regions are quite similar in most respects, the former is distinguishable by the presence of the rías, flooded river valleys, which interact strongly with the shelf up/downwelling circulation and biogeochemistry, and which locally allow upwelling to be taken advantage of by sites of intensive aquaculture. The *Gulf of Cadiz* sub-region represents a major interruption in the continuity of the system, because of its coastline configuration, unfavourable

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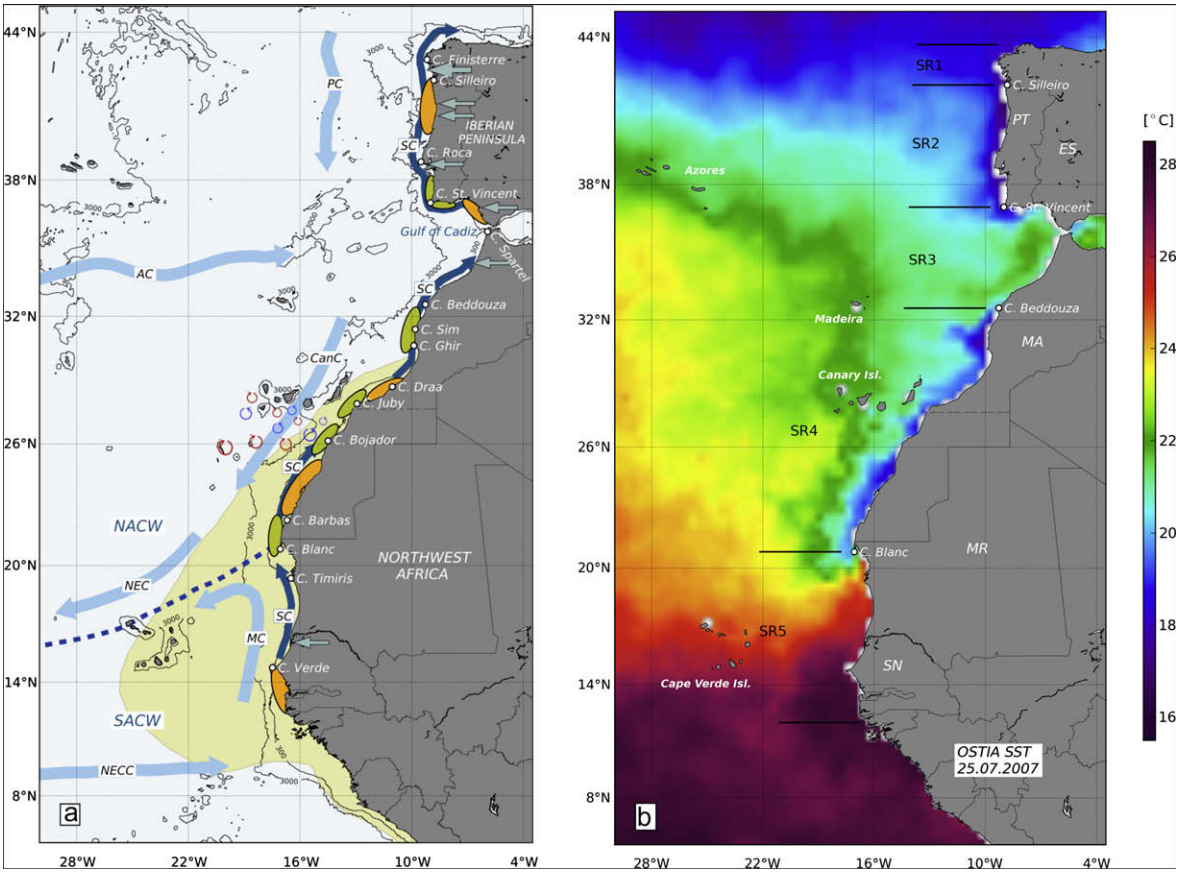

Fig. 1. (a) Schematic map of the Canary Basin showing the main currents (light blue: surface currents; dark blue: slope current), major capes, freshwater (blue arrows) and dust inputs (>10 g m^{-2} y^{-1} shaded yellow), retention (orange) and dispersion (green) zones on the shelf, frontal zone between water masses (dashed blue lines) and mesoscale eddies (blue: cyclones; red: anticyclones) south of the Canary Islands. NACW: North Atlantic Central Water; SACW: South Atlantic Central Water; AC: Azores Current; CanC: Canary Current; MC: Mauritanian Current; NEC: North equatorial Current; NECC: North equatorial Countercurrent; PC: Portuguese Current; SC: Slope Current. (b) Map of sea-surface temperature over the study area on 25 July 2007 from OSTIA (Stark et al., 2007). The locations of the five sub-regions described in the text are marked (SR1: Galician; SR2: Portuguese; SR3: Gulf of Cadiz; SR4: Moroccan; SR5: Mauritanian). PT: Portugal; ES: Spain; MA: Morocco; MR: Mauritania; SN: Senegal.

for upwelling, and its exchange of water masses with the Mediterranean Sea. The southern part of this sub-region is possibly the least known of all. Further south, the *Moroccan* sub-region between Cape Sim and Cape Blanc, which benefits from year-round upwelling, is characterized by important localized fishing grounds and a high level of mesoscale oceanographic variability arising from its geographical heterogeneity. Variations in shelf width, the presence of major capes and the perturbation represented by the Canary is-

Table 1
Ecosystem characteristics of different sub-regions in the Canary Current upwelling.

Sub-region	Geographical features	Upwelling features	Upwelled water and nutrient concentration	Hypoxia at OMZ	External inputs	Coastal–offshore export vs. retention	Main pelagic resources	Main demersal resources
Galician	Rias Capes	Summer upwelling	NACW	No	Freshwater	Short-term varying	Sardine Horse mackerel	Blue whiting Hake
42–44°N	Narrow shelf	Filaments	7–9 μM				Atlantic mackerel	Megrim
Portuguese	Rivers Capes	Summer upwelling	NACW	No	Freshwater	Export &	Sardine Horse mackerel	Snipefishes Blue whiting
37–42°N	Narrow shelf	Filaments	7–9 μM			Rretention	Chub Mackerel	Boarfish
Gulf of Cadiz	Strait (MW exchange)						Sardine	Boardfish
		Intermittent or No upwelling	NACW	No	No	Retention	Chub mackerel	Snipefishes
33–37°N	Narrow shelf		7–9 μM				Horse mackerel	Blue whiting
Moroccan	Capes Offshore islands	All year upwelling, seasonally varying	NACW/SACW	Only close to the coast at 20 N	Dust	Export & Retention	Sardine Horse mackerel	Sparids Cephalopods
21–33°N	Wide shelf	Extended Filaments and island eddies	9–15 μM				Mackerel	Hake
Mauritanian–Senegalese	Rivers Capes	Winter upwelling Offshore poleward	SACW 15–20 μM	Yes	Freshwater Dust	Retention	Sardinella Horse mackerel	Sparids Cephalopods
12–21°N	Wide shelf	regime						Hake

MW: Mediterranean Water; NACW: North Atlantic Central Water; SACW: South Atlantic Central Water; OMZ: Oxygen Minimum Zone.