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OCLE: A European open access database on climate change effects on littoral and oceanic ecosystems

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1. Introduction

Studies on historical and future distribution of marine species are frequently limited by the lack of relevant data on abiotic components (IPCC, 2014), especially when working over large areas (Robinson et al., 2017). Important advances have been achieved in the last years regarding availability of global information on physical and chemical driven forces affecting species distributions. WorldClim (Hijmans et al., 2005) marked a milestone in terrestrial species distribution studies, as it opened the opportunity to address global research studies with high resolution. Other databases including historical and projected variables in the terrestrial environment, mainly temperature and precipitation, such as Climond (Kriticos et al., 2012), Climate wizard (Girvetz et al., 2009) or Chelsea (Karger et al., 2016) have emerged recently. However, in the marine environment the number of global databases is limited. Bio-Oracle is the most valuable reference because it provides surface and benthic layers for water temperature, salinity, nutrients, chlorophyll, sea ice, current velocity, phytoplankton, primary productivity, iron and light at high resolution and global coverage (Assis et al., 2017; Tyberghein et al., 2012). Other remarkable databases are MARSPEC (Sbrocco and Barber, 2013), offering variables derived from bathymetry, slope, salinity and sea surface temperature, Aquamaps (Ready et al., 2010), focused on marine animals, or Hexacoral (Fautin and Buddemeier, 2002), with the aim to understand spatial and temporal patterns in biogeochemistry and biogeography. Some databases cover both land and sea areas, such as the MERRAclim (Vega et al., 2017), which offers decadal data of 19 derived variables of air temperature and humidity atmospheric water vapour.

Despite the important contributions of these marine databases, different important questions still require further developments. The first issue to be considered is the common absence of data on hydrodynamic variables (e.g. wave height, current speed or bottom and wind stress) with global coverage, although there is considerable evidence of their relevance in species distribution (Callaghan et al., 2015; de la Hoz et al., 2018; Ramos et al., 2014). Among these, the bottom shear stress is very important when studying benthic vegetation because its influence on their settlement and survival (Pace et al., 2017), but this kind of information does not seem to be currently available for large areas. A second concern refers to the lack of homogeneity in the time intervals used to calculate different parameters and consequent limitations for long-term multi-criteria retrospective analysis. The third issue that rises in this analysis applies to the ecological reliability of the selected parameters. Most databases only provide mean, minimum and maximum values for long periods, although many environmental triggers influencing life cycles and species distributions seem to act on extreme events occurring at shorter time scales (Galván et al., 2016; Seabra et al., 2015), especially in a climate change context (Lima and Wethey, 2012). Therefore, the formulation of biologically-meaningful parameters using datasets and increasing time resolutions arises as two key steps in order to get more realistic results. Moreover, when defining parameters for projected futures, it is essential to work with the best information available, as the General Circulation Models (GCMs), that take into account the Representative Concentration Pathways (RCPs) introduced in the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014).

Accordingly, the improvement of the available databases must address those gaps in order to adapt them to current and future needs for species distribution studies. Homogeneous and complete high resolution data, integrated at different time scales, ecological-sounded parameters, based on abiotic conditions that determine the ecology of the species of interest have to be included. Additionally, raw data have to be controlled and homogenised to guarantee the quality of the derived products. Concerning temporal periods, different resolutions should be available to allow researchers to define specific parameters for each species. Besides, data should fit to the spatial scale of the work, covering the study area with the necessary detail. Finally, the access to the data have to be free and very intuitive for users, reducing to the maximum the weight and the computing resources used for getting the information.

Trying to comply with these requirements and using the best data available, to our best knowledge, this study presents the open access database on climate change effects on littoral and oceanic ecosystems (OCLE), an ecological-driven database of present and future hazards for marine life in Europe. As a first step the database is oriented toward

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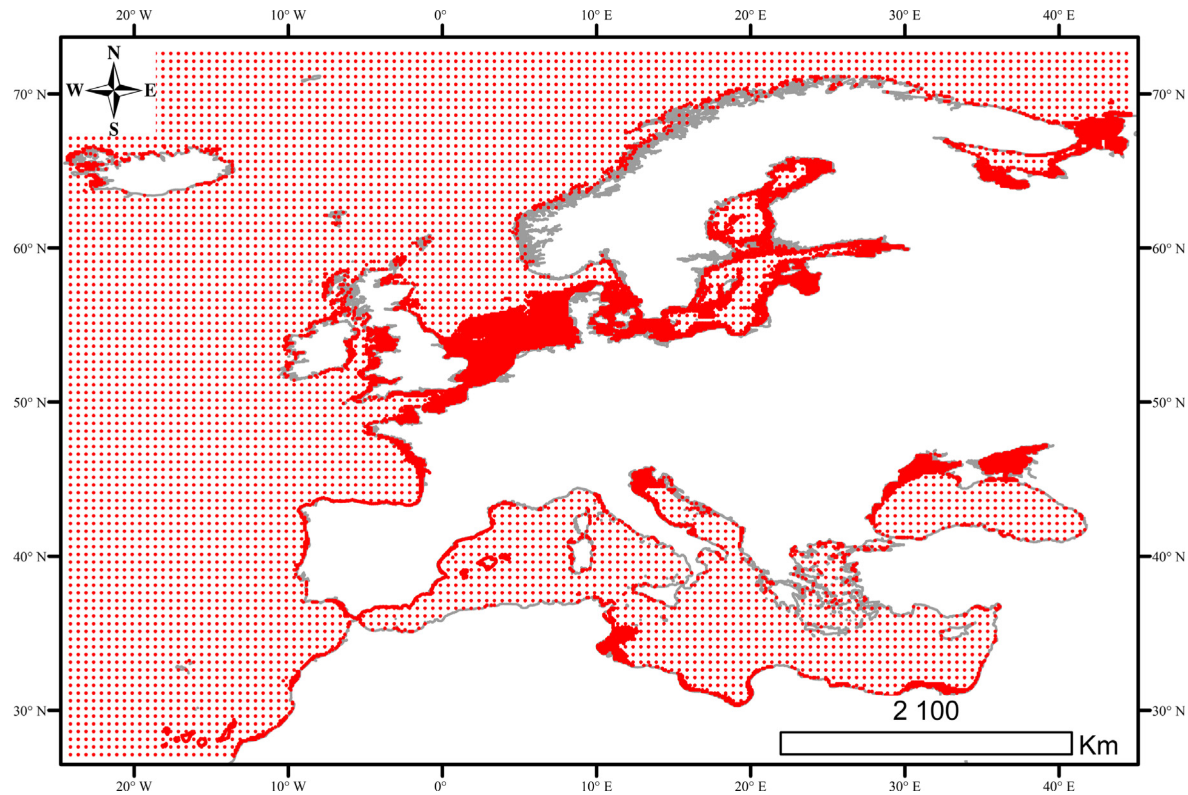

Fig. 1. Representation of the "virtual sensors" integrated in the OCLE database.

seagrasses and algae, due to their key role in the food chain of marine ecosystems, contributing to the maintenance of biodiversity and providing ecosystem services (Duarte et al., 2013; Mazarrasa et al., 2017; Ondiviela et al., 2014). However, the aim of OCLE is to provide researchers with open access accurate information for marine studies, not only for coastal studies, but also in oceanic waters.

2. Material and methods

2.1. Study area

All the regional European seas have been included in OCLE, at two different resolutions: 0.1° for coastal waters (until 50 m depth), to better characterize the potential habitat of coastal ecosystems; and, 0.5° for oceanic waters. That way, the OCLE database can provide information for a total of 18,200 points considered as "virtual sensors", of which 12,074 correspond to coastal areas and 6126 to offshore areas (Fig. 1).

2.2. Variables and parameters

The variables included in OCLE were first selected because of their functional relationship with seagrasses and macroalgae distributions. Those variables with a heterogeneous distribution in space and/or time were discarded. General meteo-oceanographic variables (hereinafter referred to as met-ocean variables) were considered first, including different physical and chemical factors, such as temperature (Fralick et al., 1990; Valle et al., 2014), light (Best et al., 2001; Larkum et al., 2006), salinity (Nejrup and Pedersen, 2008; Touchette, 2007) or nutrients (Hughes et al., 2004; Martínez et al., 2012b). Those were complemented with other variables related to the stressful conditions that limit intertidal organisms distributions, such as desiccation, a decisive survival factor characterized by the tidal range (Pearson et al., 2009), the wind speed (Lipkin et al., 1993), the significant wave height (Jones et al., 2015) and sea level (Short and Neckles, 1999), especially under future scenarios. A final group of variables regarding exposure of subtidal species to uprooting conditions was also taken into account. Stress to high energy conditions is characterized by the bottom orbital speed (Young et al., 2015), the currents speed (Infantes et al., 2011) and the, significantly more complex variable, bottom shear stress (Pace et al., 2017).

For each variable, a complete set of parameters was selected in order to reflect in a more holistic perspective the state of the environment, as a proxy of ecological processes. For historical data, the maximum, minimum, mean, standard deviation, range and percentiles 10, 25, 50, 75 and 90 were calculated at each virtual sensor, for seasonal, monthly, yearly, five-yearly and full (1985–2015) periods (Fig. 2). Besides, according to the more detailed information available and their close relationship to macrophytes distributions, some specific and relevant parameters to detect changes in extreme conditions of sea and air temperatures (i.e. number of consecutive days over the percentile 90 (Torresan et al., 2016)), and for the shear stress (i.e. number of days over 2.2 Nt/m^2 (Vousdoukas et al., 2012)) were calculated (Fig. 2). Furthermore, for future projections, the same group of parameters were calculated on a seasonal, yearly and full period, considering both the near-term (2040–2069) and the long term (2070–2099) for two RCPs, namely RCP 4.5 and RCP 8.5.

2.3. Data sources and methods

Historical data were compiled from satellite (Schuckmann et al., 2016), reanalysis (Cid et al., 2014; Donlon et al., 2012; Perez et al., 2017; Reguero et al., 2012; Saha et al., 2010; Stark et al., 2007) or *in situ* measurements (Weatherall et al., 2015).

A quality control was established along all steps. First, only validated sources were selected, either with instrumental data (Garnesson et al., 2016; Perruche et al., 2015; Saha et al., 2014, 2010; Schuckmann et al., 2016), remotely sensed information (Donlon et al., 2012) or both of them (Cid et al., 2014; Perez et al., 2017). To get a temporal and spatially homogeneous database, only sources with time series longer