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Coastal processes in northwestern Iberia, Spain

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ABSTRACT

The main coastal processes controlling water, nutrients and sediment transport are considered in the present issue, to emphasize the need for multidisciplinary approaches to achieve a proper assessment of the environmental status in coastal zones (such as the Galician area). Special emphasis has been placed upon the interpretation of local processes, within the context of a global perspective, especially for those regions with environmental properties similar to Galicia.

1. Introduction

The interest in regional studies has increased over the last decades. This interest has resulted in the publication of different Special Issues on different regions, in various oceanographic journals (Murray, 2006; Ruiz and García-Lafuente, 2006; Campos et al., 2008; Ducklow, 2008; Gomez-Gesteira et al., 2008a; Harris et al., 2008; Macklin et al., 2008; Borja and Collins, 2009). Such regional areas are an invaluable benchmark of marine environments where dependence on both anthropogenic forcing and natural variability can be tested. An example of the output of such regional studies could be the analysis of temperature trends, which constitute an important step in understanding the impact of climate change on the productivity of marine systems. Thus, although temperature variation is coherent over large spatial scales, both in the ocean and in the atmosphere, regional differences can play a key role in the conservation of ecosystems (Friedland and Hare, 2007; Gomez-Gesteira et al., 2008b; deCastro et al., 2009; Goikoetxea et al., 2009; Michel et al., 2009).

Galicia (Fig. 1) is located in the northwestern part of the Iberian Peninsula. Topographically, the area extends along 1720 km of coast and is characterized by the presence of many inlets. A complete description of the topography and the bathymetry of the area can be seen in Gomez-Gesteira et al. (2011). The *rias* are divided into inner and outer zones, according to their hydrodynamic and sedimentological characteristics (Vilas, 2002). The outer zone is located within the mouth of a *ria*; sometimes, this is protected from direct oceanic influence by small islands. The estuary lies close to the head of the *ria*, where the main river outflows.

The present state of knowledge regarding the origin of the *rias* is the consequence of an extensive and fruitful research process, with roots based on von Richthofen's (1886) to use the term *ria* to designate a type of coastline characterized by the existence of a valley occupied by the sea (Evans and Prego, 2003), taking as its prototype the Galician *Rias*.

The Galician *Rias* have been studied by geologists and physical geographers, in order to establish their origins and to establish data useful to develop an understanding on the evolution of the northwestern Iberian Peninsula (Méndez and Vilas, 2005). Pannekoek (1966a,b) has concluded that, during the Miocene, wide valleys existed at present river bodies, most of them flanked by mountainous massifs. Close to the present coast, the depths of these valleys were still far from today's sea level, i.e., the emergent zone extended farther westward, than nowadays. The sinking and flooding of these areas at the end of the Miocene, at least partially over the length of the faults, and probably an uplifting of the land, as well, set off a reactivation of the erosion processes, which penetrated the lower courses of the rivers. According to Pannekoek (1970), since the Pliocene to the present day, those valleys reached their actual amplitude as a consequence of an intense alteration and recession, retreat, regression of their slopes.

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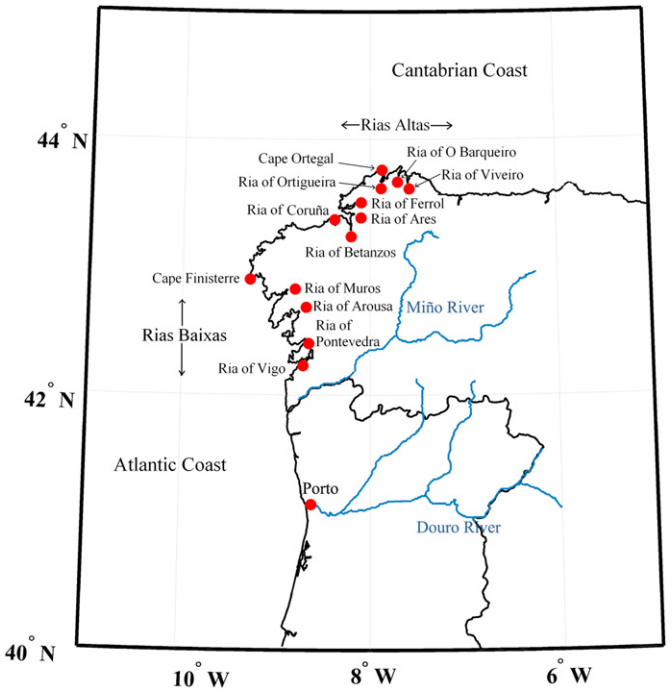

Fig. 1. Map of the area under study.

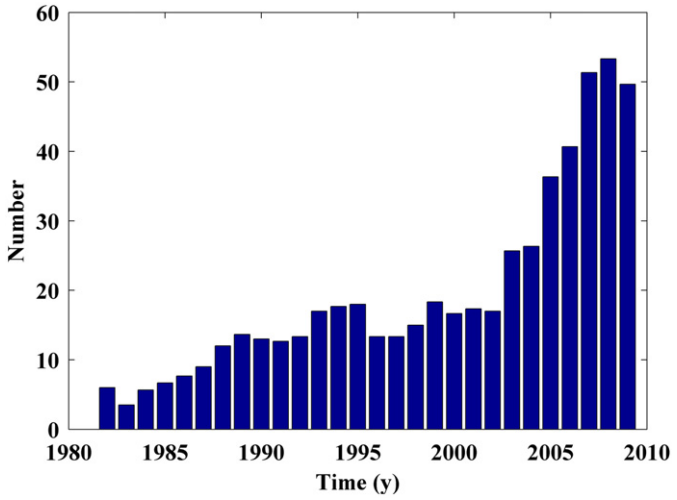

Fig. 2. Number of Standard Citation Index (SCI) publications (per year) that included the subject *ria* in the title, keyword or abstract, as consulted in SCOPUS. Data were purged to retain only references to the Galician *Rias*. Data were smoothed by means of a running average, to the previous and subsequent year.

Table 1
Annual number of SCI publications that included the subject *ria* in the title, keyword or abstract compared with the publications in other regions all over the world (as consulted in SCOPUS). Only data until 2009 have been considered.

	SCI publications in different regions			Ratio of SCI publications in the *rias* relative to publications in other regions		
	Total	From 1990 (per year)	From 2000 (per year)	Total	From 1990	From 2000
Rias	532	23	32	–	–	–
Bay of Biscay	1438	55	76	37%	42%	42%
Chesapeake Bay	3754	129	159	14%	18%	20%
Fjords	2770	81	66	19%	28%	48%

As part of the discussion about the appropriateness of applying the term *ria* to different types of recesses in the shore having different origins, Nonn (1966) defined three types of *rias* along the Galician coast. The first type corresponds to the lower part of a flooded fluvial system. The best examples of this type of *ria* are found in the Cantabrian coast, in particular, the so-called *Rias Altas*. This form can be limited to inner areas in those *rias* exposed to the west. The second type of *ria* is characterized by the preponderance of tectonics, especially because the main river bed cannot justify the width of the *ria*. For instance, the hydrographic systems in the *Ria* of Vigo, the *Ria* of Pontevedra and the *Ria* of Muros, provide proof, according to Nonn (1966), that their present flow does not explain the *rias*' dimensions. Therefore, falling or dislevelment of tectonic blocks in the emerged part appears to have been responsible for the actual configuration of the *Rias Baixas*. The third type of *ria*, according to this typology, corresponds to flooded basins altered during the Tertiary. A representative of this type within the Galician coast is the globular or ameboid form (confirmed by aerial views) of the *Ria* of Coruña.

The continental shelf adjacent to the Galician coast, together with the associated *rias*, possesses an extraordinary commercial interest for fisheries. Consequently, beyond the undoubted scientific interest of the area, knowledge on the main processes taking place in this zone facilitates largely the management of many exploited and protected species. It is worth noting that the Galician area produces around 250,000 tons of mussels per year, i.e., around 15% of the world production. Nevertheless, the Galician coast (in general) and the *rias* (in particular) were an almost neglected study area during the 19th century and the early part of the 20th century. Only during the last few decades has the area attracted the interest of scientists from different institutions. In particular, the University of Vigo, the *Instituto de Investigaciones Marinas* (CSIC) and the *Instituto Español de Oceanografía* (IEO) have undertaken most of the multidisciplinary research carried out in the area. According to SCOPUS, there is a continuous increase from the beginning of the 1980s in the number of Standard Citation Index (SCI) publications that included the subject *ria* in the title, keyword or abstract (Fig. 2). Additionally, the ratio of SCI publications between the Galician *Rias* and similar areas located all over the world has increased also during the last decades (Table 1).

Hereafter, we will advance several key processes in the Galician area that have been addressed intensively in on-going research by local research teams in collaboration with international groups.

2. Coastal processes

2.1. Physical processes

Possibly, the most important physical process along Galician coast is the existence of persistent favorable upwelling conditions (from April to September). This phenomenon not only determines the thermohaline (salinity and temperature) properties of shelf and estuarine waters, but also is responsible also for the primary production (Huthnance et al., 2002; Torres and Barton, 2007).

Coastal upwelling is due mainly to a combination of three factors: (i) the existence of a persistent wind; (ii) the presence of a solid boundary; and (iii) the apparent deviation of a moving object from its straight path within a rotating reference system