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# The Bay of Biscay: Almost two centuries inspiring global oceanography

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**Abstract :**

This Special Issue (SI) of Estuarine, Coastal and Shelf Science presents contributions from ISOBAY 17: the XVII International Symposium on the Oceanography of the Bay of Biscay. The main objective of this SI is to gather recent multidisciplinary research about the Bay of Biscay, covering different aspects from biological oceanography to marine geology and marine resources or habitat restoration and conservation. This SI aims as well to serve as a presentation platform for the most up to date scientific knowledge relating to the Bay of Biscay, from the open ocean and the deep sea to its coastal zone, and its transitional waters (estuaries, lagoons, and deltas). This common focus allowed a multidisciplinary approach in a wide range of disciplines, from biological oceanography to marine geology and integrative assessment of the marine environment. The contributing authors have explored a wide variety of these issues. The 24 selected articles provide a representative overview of the investigations carried out in this particular bay and cover the diversity of threats and opportunities faced by the marine environment of the Bay of Biscay and the people it supports. These investigations constitute a significant contribution towards an integrated knowledge of the Bay of Biscay and, hopefully, will serve as a basis for an integrative management of this region by a multi-disciplinary community of researchers, educators, and practitioners.

**Highlights**

► This SI presents contributions of the XVII International Symposium on Oceanography of Bay of Biscay. ► 24 selected articles providing a representative overview of most up to date investigations. ► Investigations from open ocean and deep sea to its coastal zone and transitional waters. ► Contributions covering the diversity of threats faced by marine environment and people it supports. ► Multidisciplinary contributions from different marine sciences and technologies.

**Keywords** : ISOBAY, North Atlantic, Cantabrian Sea, Regional seas, Global change, Climate change, Europe

## 1. Introduction

The Bay of Biscay is one of the key constituents of the northeastern Atlantic Ocean, playing an important role in the interactions between the continental shelf and the open ocean, thus influencing regional processes from mid-latitudes. Furthermore, this large gulf constitutes a transitional zone between two different ecoregions (one with predominantly boreal biota in the North and one with subtropical Atlantic/meridional biota in the South) (Fisher-Piette, 1957). Geographically, the Bay of Biscay is partially enclosed by western Europe from the coast of Northwest France (Point Penmarc'h, offshore of Brittany) to Northwest Spain (Cape Ortegal, Galicia) (Fig. 1). In total, this gulf occupies around 175,000 $km^2$. The continental shelf is narrow in the South and becomes broader in the North. The southern part of the Bay of Biscay, washing over the northern coast of Spain, is known as the Cantabrian Sea. Its average depth is 1,744 m and its greatest depth is 4,735 m (Lavin et al., 2006). As a part of the North Atlantic Ocean, the Bay of Biscay waters are warmed by the Gulf Stream and, in addition to these Atlantic influences, it receives a strong freshwater input, especially from the French rivers the Loire and Gironde. Consistently, it is a complex and highly productive area, sustaining high levels of fishing activities (Hyli et al., 2008).

## 2. Past and current research

The interest in the systematic study of the Bay of Biscay originated with the birth of the Marine Biology and the Oceanography in the mid-19$^{th}$ century, with the establishment of the first marine biology laboratories and stations (such as the Zoological Marine Station of Arcachon, founded in 1867) and the beginning of the large oceanographic expeditions. In 1844, the French zoologist Henri Milne-Edwards, together with his colleagues Jean Louis Armand de Quatrefages and Charles Émile Blanchard (all recognized naturalists at that time), carried out a big coastline sampling tour in the Bay of Biscay, including both French and Spanish coastlines, which then continued through the Mediterranean Sea (Milne-Edwards, 1880). This sampling campaign revealed a plethora of new marine species and constituted a striking event in marine zoology, however in accounts of the Bay of Biscay historical oceanography it was only mentioned in passing or neglected.

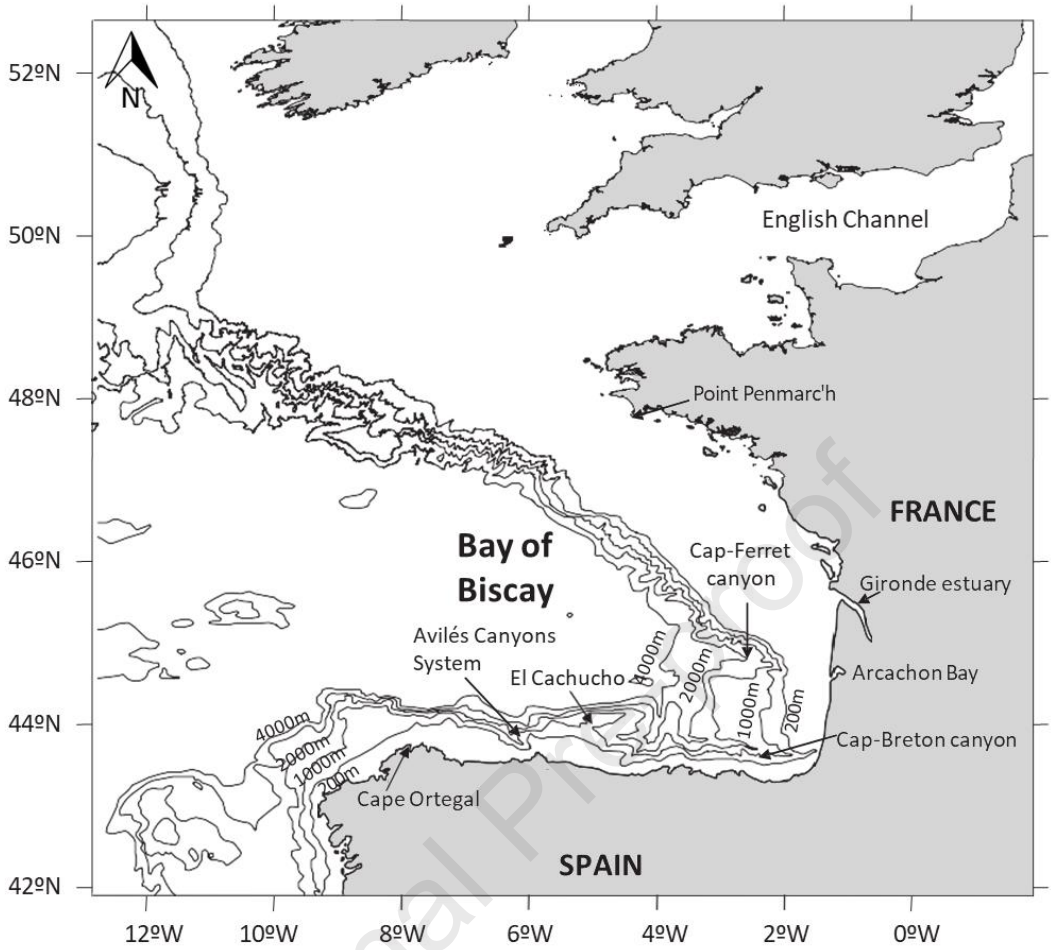



**Fig 1.** The Bay of Biscay, showing the most important characteristics and depth contours.

In July 1869, during the second H.M.S. Porcupine campaign, led by John Gwyn Jeffreys, the first dredging at more than 4,000 m depth was carried out collecting specimens of all the large groups of marine animals. The impact of this discovery in the contemporary scientific community was immense (Laubier and Monniot, 1985) and paved the way for the first French deep-sea expeditions in the Bay of Biscay. Thereby, some years later, in July 1880, the French expedition of the *Travailleur* began its journey in the Bay of Biscay, sampling from 300 to 2,600 m depth and uncovering new deep-sea forms and even some mollusc taxa thought to be extinct (Jeffreys, 1880; Dolan, 2020). The cruise was headed by H. Milne-Edwards and included other outstanding French and British scientists of that time, as Alphonse Milne-Edwards (the son of the former), Leopold Folin or Jeffreys. This exploration was very successful in terms of both science and scientific impact, providing

the first Standard Citation Index (SCI) publication of oceanography of the Bay of Biscay: "The French Deep-Sea Exploration in the Bay of Biscay" published by Jeffreys in the journal *Nature* (Jeffreys, 1880; Fig. 2). Until the end of the 1960s, research in the Bay of Biscay was undertaken mainly under individually based investigations and specific topics (Borja and Collins, 2009). Thereafter cooperative research between different institutions/countries, promoted by the establishment of the Iberian Symposium on Marine Benthic Studies -SIEBM- (San Sebastián, Spain, 1979) and the 'International Symposium on the Oceanography of the Bay of Biscay (Oviedo, Spain, 1988), started to increase significantly and thus, the number of related SCI publications (Fig. 2).

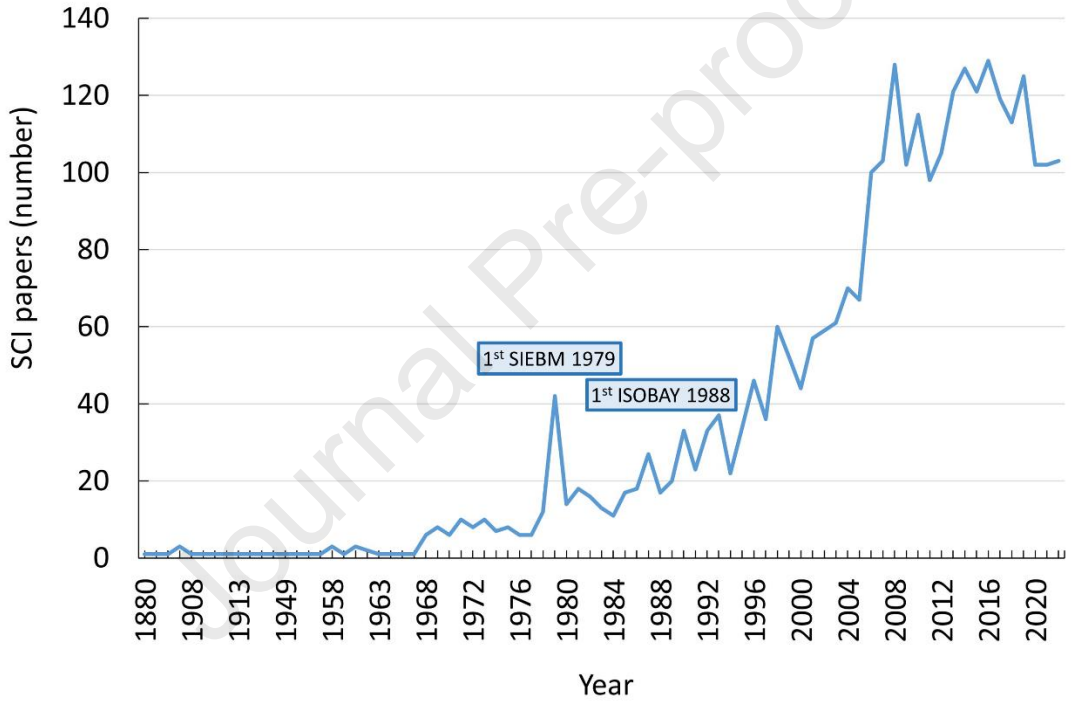



**Fig. 2.** Standard Citation Index (SCI) publications, including the subject 'Bay of Biscay' in the title, keywords or abstract, from 1880 to 2022 (retrieved from SCOPUS® in December 2022).

The 'First Workshop on Cantabrian Sea Oceanography' (the seed that later became the 'International Symposium on the Oceanography of the Bay of Biscay' - ISOBAY) was celebrated in the University of Oviedo from the third to fifth October 1988 and brought together a small group of scientists from Galicia, Asturias, the Basque Country, and Catalonia. Researchers at the workshop documented, for the first time, the Navidad slope

current and its ecological impacts. This current spans the whole Bay of Biscay and represents a good example of the type of oceanographic linkages that justify a regional congress like ISOBAY. This initial event also reported the widespread occurrence of deep-water coral outcrops in the Avilés submarine Canyons System, when Spain was a brand-new member of the European Union. Today, those fascinating systems are protected by the Natura 2000 European Network as a site of community importance (SCI).

Since 1988, the ISOBAY has been offered every two years, alternatively in Spain and France, constituting an excellent opportunity for both early career and senior researchers to meet and network with many other researchers interested in the study of the Bay of Biscay. The multidisciplinary character of this symposium is clearly reflected in the broad list of topics that it covers edition after edition: *Marine Biodiversity and Ecosystem Function; Marine Geology; Biological, Chemical and Physical Oceanography; Threatened Marine Ecosystems and Endangered Species; Exploitation, Management and Conservation of Marine Resources; Water Quality; Blue Biotechnology and Marine Genetic Resources; Global Change, Invasive Species and Anthropogenic Pressure; Science-Policy Communication; Governance; Adaptive Management and Education* and *Coastal Development and Engineering*.

In particular, this SI has dealt with the following topics and authors: *Biodiversity and Biological Oceanography* (Anadón et al., this issue; Arias and Paxton, this issue; Escobar-Ortega et al., this issue; Frutos and Sorbe, this issue; García-Guillén et al., this issue a, b; Ríos et al., this issue; López-Alonso et al., this issue); *Habitats and Ecosystem Function* (Corrales et al., this issue; Modica et al., this issue; Rodríguez-Basalo et al., this issue); *Marine geology* (Belleney et al.; Gómez-Ballesteros et al., this issue); *Threatened Marine Ecosystems and Endangered Species* (Abad-Uribarren et al., this issue; Sánchez et al., this issue); *Exploitation, Management and Conservation of Marine Resources* (Higgins et al., this issue; Landa et al., this issue; Pennino et al., this issue; de la Uz et al., this issue;) and *Global Change, Invasive Species and Anthropogenic Pressure* (Fernández et al., this issue; Fernández-Rodríguez et al., this issue; Garnier et al., this issue; Izquierdo et al., this issue; Wethey and Woodin, this issue).

A major emphasis of the editors while preparing this SI has been to highlight the relevance and implications of the study of marine biodiversity in the present scenario of global change, which is impacting virtually all marine life. A recent global study concluded that

up to 90% of marine species could be at high or critical risk, with species at risk across 85% of their native distributions if greenhouse gas emissions continue at current rates (Boyce et al., 2022). These authors evaluated threats faced by nearly 25,000 marine species and found that almost 90% are expected to disappear by 2100, as climate change drives disturbances to the ecosystem and further biodiversity loss in the oceans. In the same way, Wethey and Woodin (this issue) studied the probability of fatal heat waves in the European lugworm *Arenicola marina* using model distributions. The patterns revealed by the models were consistent with observations *in situ* and predict the complete disappearance of *A. marina* from the Mediterranean Sea and the Bay of Biscay and its restriction to the upwelling zone on western Iberia and to the Atlantic coast of Europe (north of 45°N) in the 21$^{st}$ century. The trend towards an increased incidence of marine heatwaves due to climate change poses a serious threat to coastal ecosystems. Izquierdo et al. (this issue) examined the incidence, duration, and magnitude of marine heatwaves from 1998 to 2019 in the central Cantabrian Sea and revealed that they coincided with documented shifts in the abundance and distribution of macroalgae. This triggered abrupt changes in the structure of intertidal communities of the Cantabrian Sea.

Our knowledge on the actual biodiversity of the Bay of Biscay is still far from comprehensive. One of the first attempts to roughly approach this task was the benthic faunal inventory of the Biogas and Incal oceanographic cruises, which reported a diversity of 1,096 species (Laubier and Monniot, 1985). However, this number is likely greatly underestimated, Ríos et al. (this issue) reported 1,015 species of fauna only from the Avilés Canyons System and its boundaries (central Cantabrian Sea). In addition to that thousand animal species, should be added those that occur in the intertidal and estuarine areas and the pelagic species. Which, being conservative, could add up to a total close to 2,000 species of marine animals. And the actual diversity of Bay of Biscay continues to be unraveled as evidenced by several detailed and multidisciplinary contributions of this SI. New species records of different animal phyla (Anadón et al., this issue; Fernández-Rodríguez et al., this issue; García-Guillén et al., this issue; López-Alonso et al., this issue; Ríos et al., 2022) and even new species (i.e. the stilipedid amphipod *Stilipes lagarderei* Frutos and Sorbe, this issue) have been discovered. Those subsequently increase the known biodiversity of the Bay of Biscay and concur with previous studies in considering this gulf as a faunally rich area of the northeastern Atlantic. As a specific example, some taxonomic groups of invertebrates, like ophiuroid echinoderms, appeared

to be richer at equivalent depths, than in other Atlantic areas, such as the Rockall Trough and the Gay Head-Bermuda regions (Laubier and Monniot, 1985).

## 3. Perspectives for the future and final remarks

Global change and warming oceans are driving marine species into deeper, more northern, and cooler locations, affecting the dynamics and composition of marine communities in a radical and unprecedented way. Regional seas, such as the Bay of Biscay, are especially vulnerable to these recent changes in climate and oceanographic conditions. Furthermore, the Bay of Biscay is a densely populated area with large villages, towns, and cities along its coastline. This means that it is subjected to additional great anthropogenic pressure.

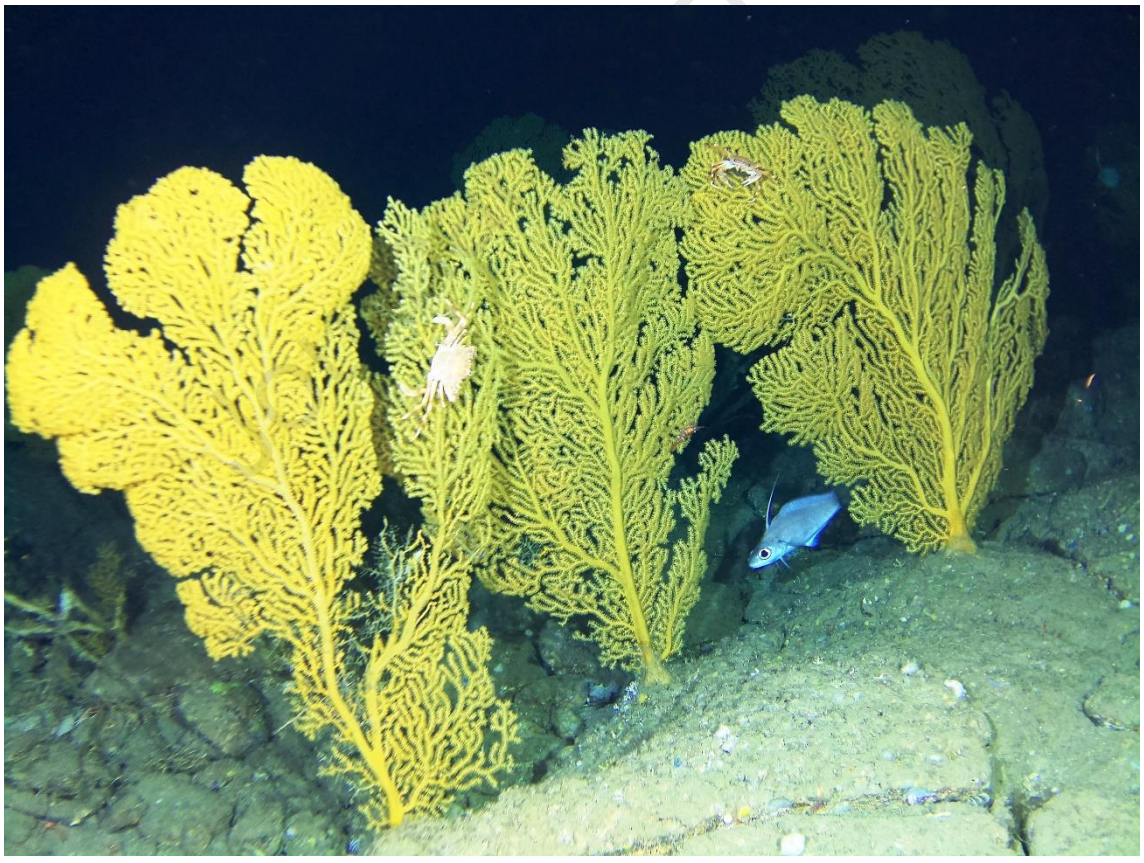
An accurate knowledge of the species diversity, together with its biology and ecology, from estuarine, coastal, continental shelf and deep-sea ecosystems is an imperative requirement in order to protect estuarine and marine environments in the current context of global change and the biodiversity loss. The remarkable increase in biodiversity studies over recent years entails a pressing need for an updated inventory of the whole fauna and flora of the Bay of Biscay, including both Spanish and French sites. This inventory on biodiversity would facilitate the development of future adaptive management and marine policies in a collaborative way for the two countries.

The information generated by the contributions of this SI is very important to ensure the survival of the European most vulnerable marine species and habitats and for the creation of new protected areas under the Natura 2000 network (N2000). Nowadays, the N2000 encompasses over 27,300 individual sites, altogether covering an area of more than 1.1 million $km^2$. This corresponds to 18% of the European land area of the European Union (EU) Member States, and almost 10% of the total EU marine area (over 550,000 $km^2$). Currently, the Bay of Biscay harbours 94 protected sites, including 46 Sites of Community Importance (SCIs), 12 Special Areas of Conservation (SACs), 1 Marine Protected Area (MPA) (Fig. 3), and 35 Birds Directive Sites (SPA).

Within the Bay of Biscay, some environments such as estuaries, gorgonian forests the deep-sea coral outcrops are particularly fragile. The estuaries are transitional ecosystems with poorly defined and shifting boundaries, thus, adaptation in and around estuaries, to

192 ensure the future resilience of both the natural environment and the population that are
193 located alongside is an increasingly pressing need. Deep-sea coral reefs, dominated by
194 the white corals, *Desmophyllum pertusum* and *Madrepora oculata*, and gorgonian forests
195 of *Placogorgia graciosa* (Fig. 3) provide physical habitat and shelter for many marine
196 organisms and are considered as key marine habitats. Although, they are protected under
197 the European Union Habitats Directive (Habitat 1170: Reefs) they should continue to be
198 the focus of conservation efforts and forthcoming studies should continue to try to identify
199 vulnerable habitats and biological communities formed/sustained by deep-water corals.

200 The study of processes in environments ranging from estuarine to deepest marine areas is
201 imperative to fully understand the complex biological and physical-chemical
202 relationships in the Bay of Biscay. Studies of land-sea interactions, coastal anthropogenic
203 activities, estuarine pollution, and alien/invasive species should be integrated into
204 ongoing and future projects concerning ecosystem-based management (EBM).



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206 **Fig. 3.** Gorgonian forest of *Placogorgia graciosa* from 517 m depth in the MPA El
207 Cachucho – Le Danois Bank (Photo by IEO-ECOMARG).

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**The Bay of Biscay: almost two centuries inspiring global oceanography**

**HIGHLIGHTS**

This SI presents contributions of the XVII International Symposium on Oceanography of Bay of Biscay

24 selected articles providing a representative overview of most up to date investigations

Investigations from open ocean and deep sea to its coastal zone and transitional waters

Contributions covering the diversity of threats faced by marine environment and people it supports

Multidisciplinary contributions from different marine sciences and technologies

**Declaration of interests**

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: