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Planktonic Ctenophora of the Madeira Archipelago (Northeastern Atlantic)

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Abstract

Ctenophores are fragile gelatinous organisms whose diversity and distribution are relatively unknown. For the first time, the occurrence of four planktonic species, namely *Ocyropsis crystallina, Eurhamphaea vexilligera, Cestum veneris,* and *Beroe* sp., was reported from Madeira Archipelago waters (NE subtropical Atlantic). This report represents the northernmost records in the Eastern Atlantic Ocean for *O. crystallina* and *E. vexilligera*.

Key words: Beroida, Cestida, Lobata, subtropical Atlantic

Introduction

Madeira Archipelago is one of two Portuguese island systems, including five major islands, Madeira, Porto Santo, and the three Desertas islands (Ilhéu Chão, Deserta Grande and Bugio). About 300 km southward, the small islands of Selvagem Grande and Selvagem Pequena are also part of the archipelago. The archipelago is located at the North Atlantic Subtropical Gyre's eastern boundary, with dominant north-eastern trade winds and typical oligotrophic conditions (Longhurst *et al.* 1995). The island system is mainly influenced by the Azores Current, which joins the Canary Current north and around Madeira Island (Sala *et al.* 2013). Madeira archipelago is one of the four Macaronesian island systems in the Eastern Atlantic (north to south: Azores, Madeira, Canary Islands, and Cape Verde) (Freitas *et al.* 2019). Despite its oceanic nature, marine biodiversity research in Madeira has been mainly focused on benthic invertebrates (*e.g.*, Wirtz 2007; Alves *et al.* 2019; Cacabelos *et al.* 2019; Ramalhosa *et al.* 2021), fish (Ribeiro *et al.* 2005; Wirtz *et al.* 2008; Biscoito *et al.* 2018), and plankton diversity mainly restricted to phytoplankton (Kaufmann *et al.* 2015; Narciso *et al.* 2019). However, Ctenophora —a taxon included among macro gelatinous zooplankton—remains greatly unexplored in Madeira waters.

Despite their apparent biological *"simplicity"* and high water content, ctenophores are ecologically important in the marine environment. They are exclusively carnivorous (Haddock 2007) but also provide prey (Diaz Briz *et al.* 2017) and habitat for various organisms (Ohtsuka *et al.* 2009). In the last decades, ctenophores have attracted rising attention due to their fast growth leading to bloom events (Sullivan *et al.* 2001; Purcell 2005) but also due to the consequences of a particular species invasion (*Mnemiopsis leidyi* A. Agassiz, 1865) in several ecosystems (Knowler 2005; Boersma *et al.* 2007; Dinasquet *et al.* 2012). Despite ctenophores being distributed in all global ocean basins, they are still poorly studied compared to other gelatinous zooplankton taxa. To date, nearly 250 species have been

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described on a global scale (Giribet & Edgecombe 2020). This gap in knowledge is related to these organisms' fragility, usually destroyed by classical plankton net sampling and the challenge of its preservation (Thibault-botha & Bowen 2004; Engell-Sørensen *et al.* 2009). However, the technological evolution of research equipment, the simultaneous increase of SCUBA diving activities and advances in underwater photography increased ctenophore diversity and distribution records worldwide (Deidun 2011; Gibbon *et al.* 2021; Hidaka *et al.* 2021). Despite these developments, their diversity is still underestimated due to uneven sampling efforts, both geographically and between shallow and deep-sea habitats

In the Atlantic Ocean, ctenophore diversity has been mainly studied along the western coasts: 20 species have been reported in southern regions and around 19 from north American waters (Mayer 1912; Oliveira & Migotto 2006; Migotto & Marques 2007; Oliveira *et al.* 2016; Dutto *et al.* 2017). In the Eastern Atlantic, studies have been primarily concentrated in South Africa, with nine species and six morphospecies (Gibbons *et al.* 2021) and approximately nine species in the European North Atlantic (Greve 1975; Hansson 2006; Licandro *et al.* 2015). Currently, 16 planktonic ctenophore species have been recorded in Macaronesia: 15 in the Canary Islands, six in Cape Verde, and three in the Azores (Chun 1898; Gueroun *et al.* 2021). To date, Madeira's ctenophore records were restricted to a single benthic species, *Vallicula multiformis* Rankin, 1965 (Wirtz 1998).

Given the ecological importance of gelatinous zooplankton, updated information on local diversity is essential. This work represents the first record of planktonic ctenophores in the archipelago of Madeira.

Material and Methods

During 2020 and 2021 surveys and scientific dives in Madeira and Porto Santo islands, different species of ctenophores were opportunistically observed and recorded in the field (GoPro Hero 7, Paralenz Dive Camera Plus), and when possible, individually collected using plastic bags and glass jars (Fig. 1, Table 1). Collected specimens were kept in containers filled with seawater for transport to the laboratory. Ctenophores were then carefully placed in a petri dish with seawater, and images were taken using an Olympus® TG-6 camera (macro setting) on the same day.

TABLE 1. Geolocalization and depth of the ctenophores observed and sampled (examined material) in Porto Santo and Madeira islands (Madeira archipelago)

Species	Island	Date	Coordinates	Depth (m)	Note
Eurhamphaea vexilligera	Porto Santo	13-Oct-20	32°59'50.64"N 16°23'01"W	0-6	observation
			33°00'13.21"N 16°23'34"W	0-6	observation
		14-Oct-20	33°00'18.72"N 16°22'13"W	0-6	Specimen studied (halotype 1)
			33°00'19.08"N 16°22'13"W	0-6	Specimen studied (halotype 2)
			33°03'45.00"N 16°18'59"W	0-1	Specimen studied (halotype 3)
		16-Oct-20	33°03'44.28"N 16°18'59"W	0-1	observation
			33°03'03.60"N 16°17'04"W	0-6	observation
			33°03'13.68"N 16°17'03"W	0-6	observation
		17-Oct-20	33°02'39.16" N 16°17'36"W	0-6	observation
		07-Dec-20	33°03'01.00"N 16°19'38"W	0-6	observation
		08-Dec-20	33°02'56.10"N 16°18'36"W	0-6	observation
Ocyropsis crystallina	Porto Santo	14-Oct-20	33°00'18.72"N 16°22'13"W	0-6	observation
			33°00'19.08"N 16°22'13"W	0-6	Specimen studied
Cestum veneris	Porto Santo	10-Dec-20	33°03'05.60"N 16°20'09"W	12	Specimen studied
Beroe sp. (*cucumis*?)	Madeira	02-Mar-21	32°38'22.07"N 16°49'50"W	0-5	Specimen studied

Identification of the specimens (observed and collected) was performed based on Mayer (1912), Mianzan (1999), Migotto & Marques (2006), and Mills & Haddock (2007). Unfortunately, we were not successful in preserving voucher specimens of the collected ctenophores.

Species occurrence data presented in Figure 5 was collected using the Global Biodiversity Information Facility database (GBIF 2021), the Ocean Biogeographic Information System (OBIS 2021) as well as published literature (see supplementary material).

Results

In total, four new and distinctive planktonic ctenophores were recorded for the first time in Madeira waters (Table 1, Fig. 1): three species were recorded in Porto Santo (*Eurhamphaea vexilligera, Ocyropsis crystallina*, and *Cestum veneris*) and one in Madeira Island (*Beroe* sp., cf *cucumis*). *Eurhamphaea vexilligera* was the most common with seven observations. Only two specimens of *Ocyropsis crystallina*, one of *Cestum veneris* and one of *Beroe* sp. were observed.

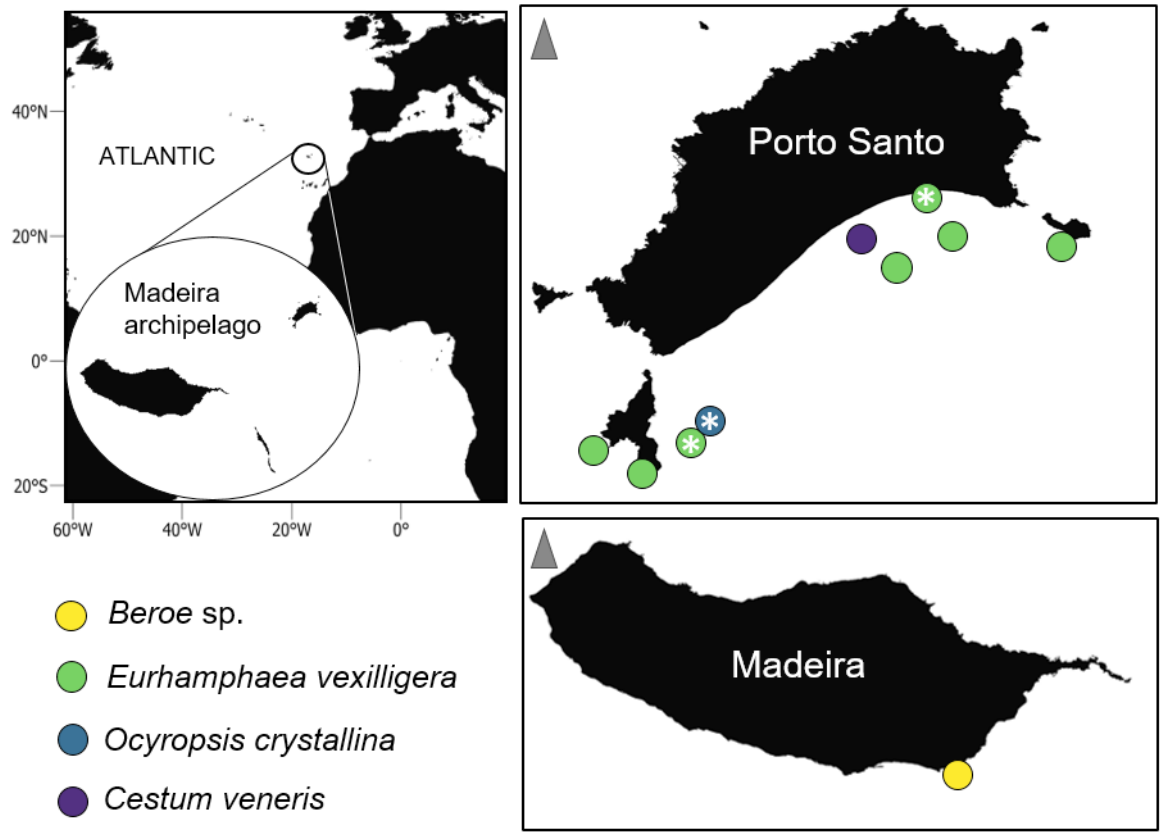

FIGURE 1. Madeira Archipelago including locations of ctenophore observations and collections (*)

Systematic part

Class Tentaculata

Order Lobata

Family Eurhamphaeidae

***Eurhamphaea vexilligera* Gegenbaur, 1856**
(Table 1, Fig. 2)

Synonym: *Mnemia elegans* M. Sars, 1856

Examined material: East coast of Ilhéu da Cal, Porto Santo Island, 33°00'18"N 16°22'13"W and 33°00'19"N 16°22'13.08"W. Several adults were observed during SCUBA diving, and two individuals were collected between 2 and 6 m depth. In Porto Santo harbour (33°3'45"N 16°18'59"W), one specimen was collected at the sea surface (0.5 m depth).

Description: Overall, body length of the sampled specimens varied from three to six cm. The biggest specimen, around 10 cm, was observed *in situ* (West coast of Ilhéu da Cal, 33°00'13"N 16°23'34"W). The body was elongated, narrow with a noticeable compression in the tentacular axis (Fig. 2A). Two horn-shaped processes terminating in the long flexible filament are drawn out at the aboral apex (Fig. 2B). Subtentacular ctene rows extend onto these processes. Reddish-brown ink vesicles with bioluminescent properties follow the path of the substomodeal meridional canals (Fig. 2C).

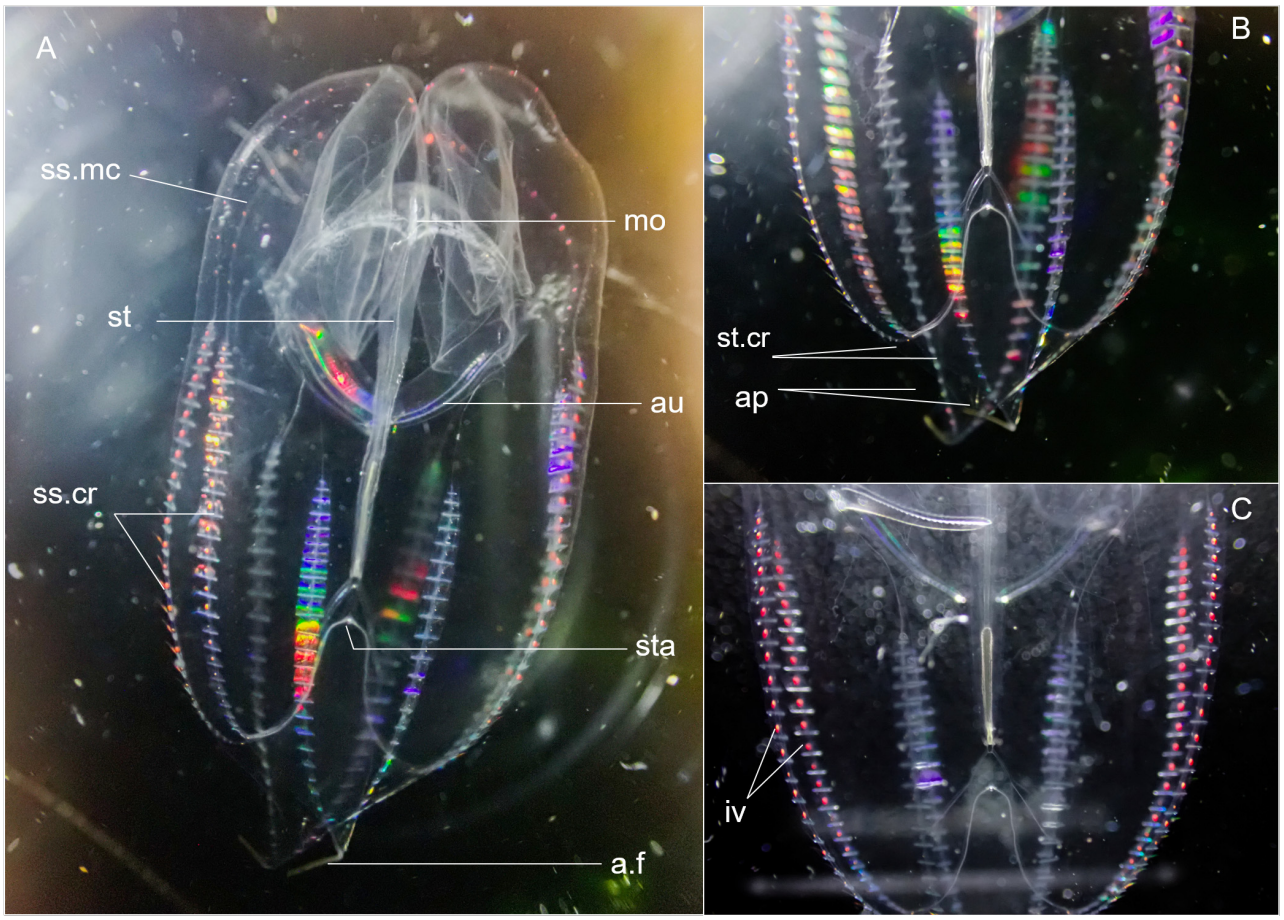

FIGURE 2. *Eurhamphaea vexilligera* Gegenbaur, 1856. **A,** total view of an adult in the stomodaeal plane; **B**, view of the aboral portion of the body in the stomodaeal plane; **C**, view of a body section in the stomodaeal plane. Legends: a.f, aboral process/filament; ap, apical horn-shape; au, auricle; i.v, ink vesicle; mo, mouth; ss.c, substomdaeal ctene row; ss.mc, substomodaeal meridional canal; sta, statocysts; st.cr, subtentacular ctene row; st, stomodaeum (pharynx). Photo credits: S.K.M Gueroun

Family Ocyropsidae

Ocyropsis crystallina Rang, 1827

(Table 1, Fig. 3)

Synonym: *Ocyroe crystallina* Rang, 1827

Examined material: East coast of Ilhéu da Cal, Porto Santo Island, 33°00'19"N 16°22'13"W. Two individuals were observed during SCUBA diving; one specimen was collected between 2 and 6 m depth.

Description: Body laterally compressed with two large flapping oral lobes. The auricles are flat and ribbon-like; their narrow edges are lined with long cilia. The stomodaeum is flat, with broadsides constricted near the middle (Fig. 3).

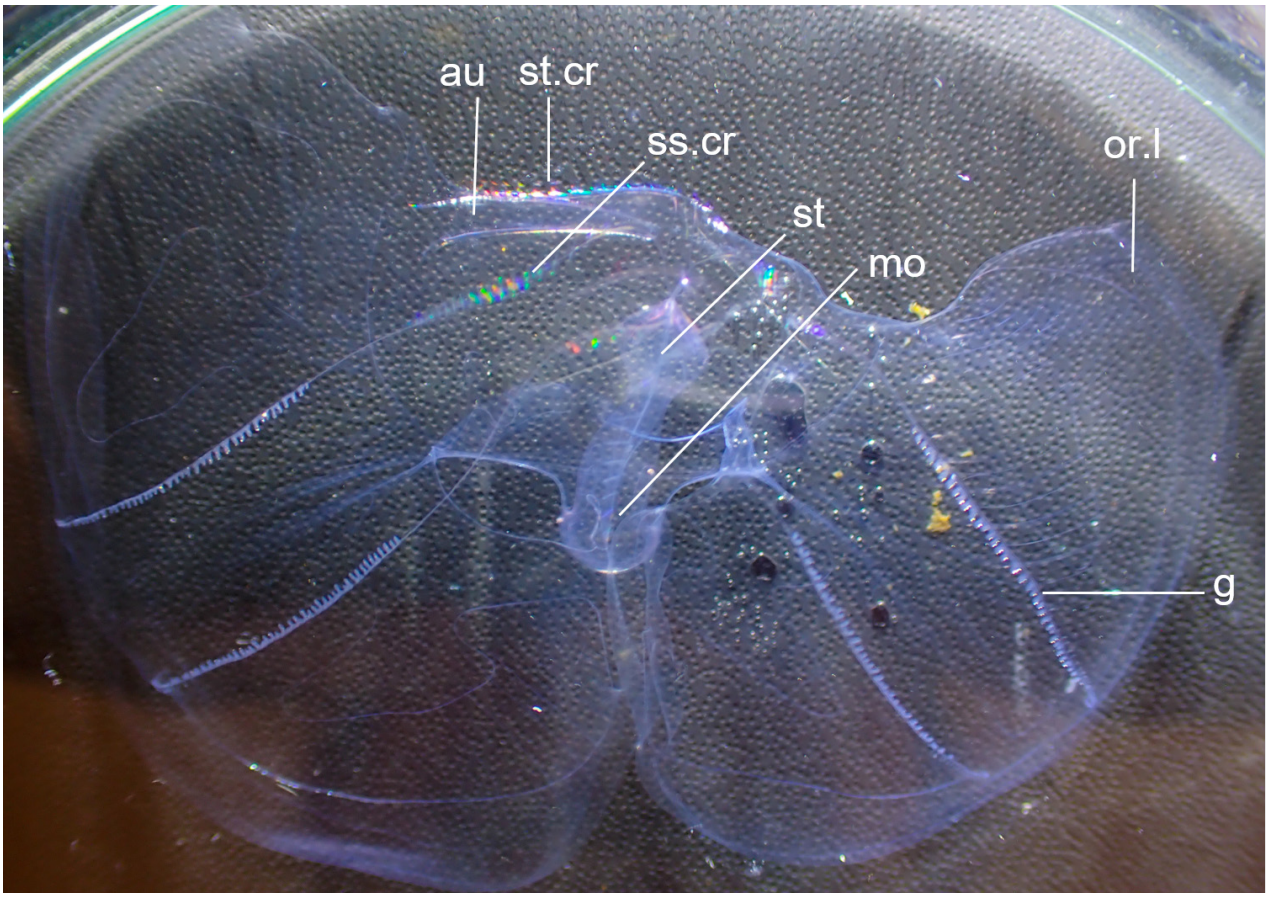

FIGURE 3. *Ocyropsis crystallina* Rang, 1827. Legends: *au*, auricle; *mo*, mouth; *g*, gonads, *or.l*, oral lobe; *ss.cr*, substomdaeal ctene row; *st.cr*, subtentacular ctene row; *sto*, stomodaeal (pharynx). Photo credit: S.K.M. Gueroun

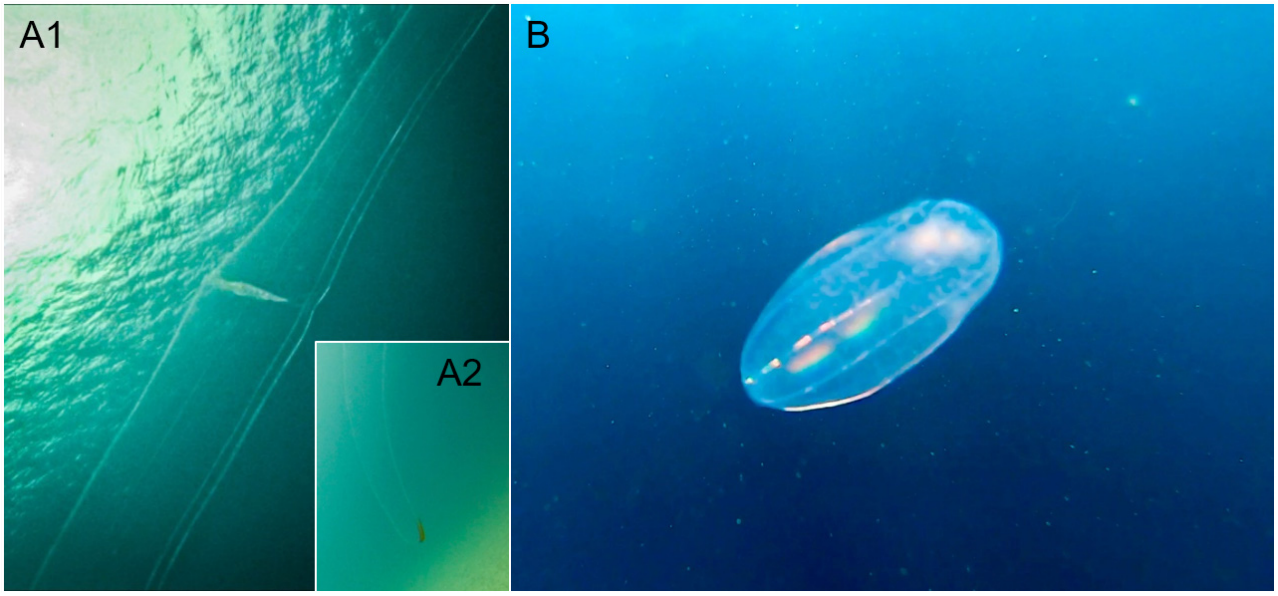

FIGURE 4. Photographies of **(A1)** *Cestum veneris* Lesueur, 1813 and **(A2)** the purplish-black pigment on its wingtips; **(B)** *Beroe* sp. Müller, 1776. Photo credit: *C. veneris*: F. Gizzi; *Beroe* sp.: M. Buzinkai

Order Cestida

Family Cestidae

***Cestum veneris* Lesueur, 1813**
(Table 1, Fig. 4A)

Synonymes: *Cestus pectinalis* Bigelow, 1904; *Cestus veneris* Chun, 1879

Examined material: Southeast Porto Santo Island, 33°03'05"N 16°20'09"W. One specimen was observed at 12 m depth, near the sand floor, during a SCUBA dive.

Description: Body laterally expanded and flattened, long and ribbon-like, around 1 m in width, transparent. Presence of purplish-black pigment on its wingtips (brown-yellowish colour on the video record due to the light spectrum gradient) (Fig. 4A2).

Remark: While no individual was clearly photographed, some reports indicate *C. veneris* occurrence in the southern part of the Madeira Island (Peter Wirtz *pers. comm*).

Class Nuda

Order Beroida

Family Beroidae

Genus *Beroe* sp. (cf *cucumis*) Müller, 1776
(Table 1, Fig. 4B)

Examined material: South Madeira Island, 32°38'22''N 16°49'50''W. One specimen was observed at around 2 m depth during a recreational free dive.

Description: Body cylindrical, flattened, opaque, without tentacles. Ctene rows with anastomosed canals.

Remark: The resolution of the photographed specimen is low due to the recording quality (GoPro Hero 7). Only two *Beroe* species have been recorded in Macaronesia: *Beroe cucumis* (Azores and Canary Islands) and *Beroe ovata* (Canary Islands) (Gueroun *et al.* 2021). As *B. ovata* aboral part tends to be wider than in *B. cucumis,* the specimen recorded in Madeira is more likely a *B. cucumis*.

Discussion

Ctenophores are fragile organisms that are not easily collected by nets, resulting in a general underestimation of their species richness, abundance, and ecological importance. During the last years, most ctenophore reports came from diving surveys and submersible records. Harbison (1985) suggested that ctenophores richness is mainly distributed in ocean deep-water, adding a layer of complexity/challenge for ctenophore diversity research.

Observations of *O. crystallina, E. vexilligera*, *C. veneris*, and *Beroe* sp. are not new in the Atlantic Ocean (Fig. 5). These ctenophores have mainly been recorded in the western Atlantic, with most of the observations ranging between 0 and 40° latitudes. The nearest records have been: for *E. vexilligera* in the Canary Islands (Chun 1898), *O. crystallina* in the Canary Islands and Cape Verde (Moro *et al.* 2013; Christiansen *et al.* 2016), and *C. veneris* and *Beroe* spp. in three archipelagos (Azores, Canary Islands, and Cape Verde) (Chun 1898; Mayer 1912; Christiansen *et al.* 2016).

Although *E. vexilligera, O. crystallina,* and *C. veneris* are often considered epipelagic species (Harbison *et al.* 1978; Oliveira *et al.* 2016), specimens have been collected or observed in the mesopelagic zone (Harbison & Miller 1986; Oliveira & Migotto 2006; Lindsay *et al.* 2015; Hidaka *et al.* 2021). As carnivorous organisms, *E. vexilligera* preys on copepods, ostracods, siphonophores, and small pteropods. *O. crystallina* feeds on siphonophores,

other ctenophores, large copepods, pteropods, amphipods, small fishes, and euphausiids. *C. veneris* preys on copepods, and *Beroe* spp. predate on other ctenophores and salps (Harbison *et al.* 1978).

Compared to other marine organisms, information on gelatinous zooplankton's functional roles in all marine ecosystems is still sparse. With such a lack of knowledge, more research is needed given the fact that (i) recent studies highlighted the importance of the so-called "*jelly web*" in planktonic oceanic food webs (Chi *et al.* 2020) and their role in pelagic-benthic coupling (Sweetman *et al.* 2014; Sweetman & Chapman 2015); (ii) some ctenophores present a foreseeable invasive behaviour and proliferation potential; (iii) ctenophores can host different parasites (Martorelli 2001; San Martín *et al.* 2021) that might negatively affect other organisms and higher trophic levels. In this context, the present study takes place to increase our knowledge of gelatinous zooplankton in the Macaronesia region and particularly in the Madeira Archipelago (Gueroun *et al.* 2021).

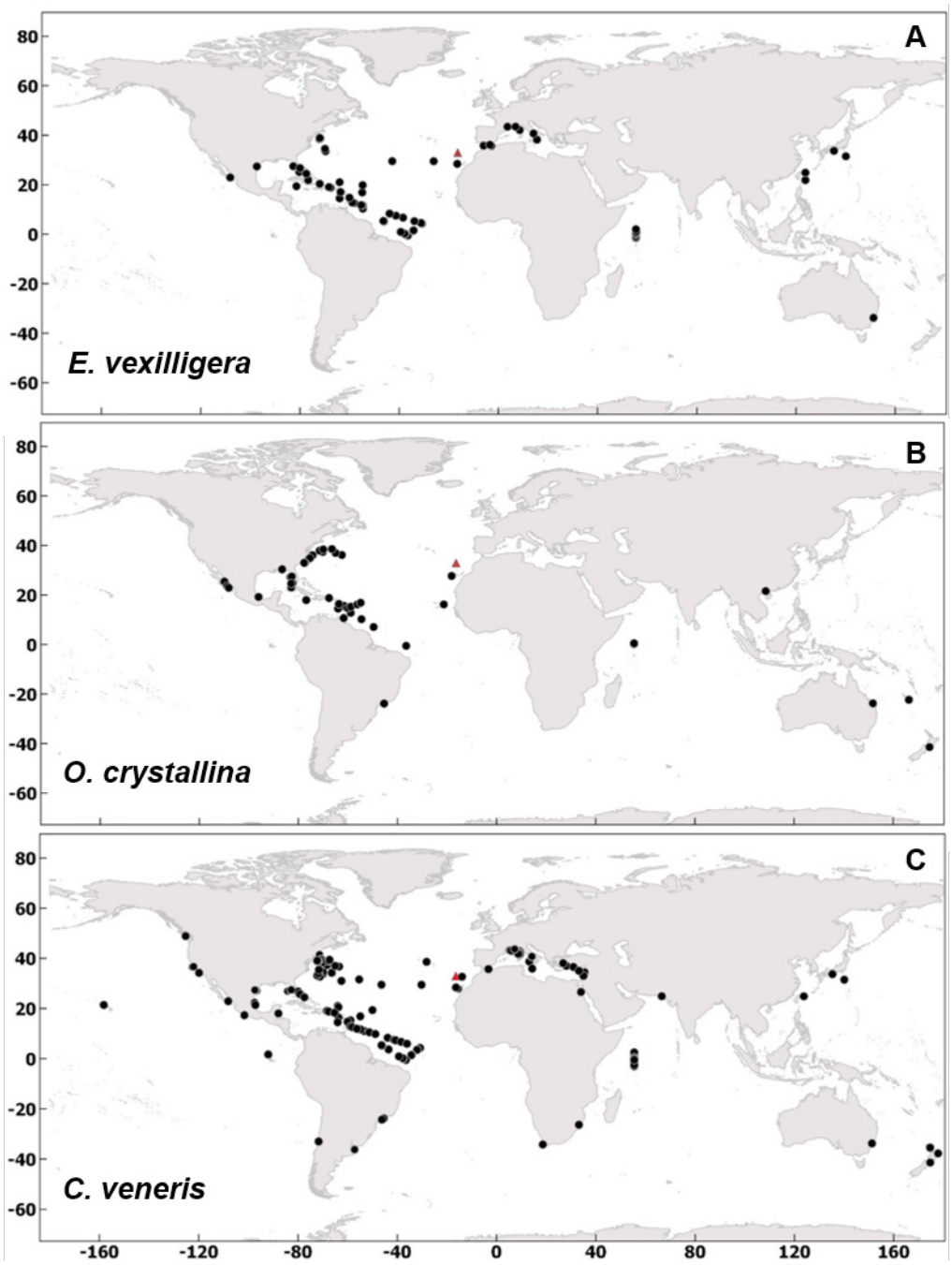

FIGURE 5. World distribution of (**A)** *E.vexilligera,* **(B)** *O. crystallina,* and (**C)** *C. veneris*. Red triangle: present records in Madeira Archipelago

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