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First record of the abyssal bivalve *Halicardia flexuosa* (Bivalvia: Verticordiidae) in the Bay of Biscay

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Abstract

The occurrence of the flexed verticord, *Halicardia flexuosa* (Verrill & S. Smith [in Verrill], 1881), is reported for the first time from the Bay of Biscay (North Iberian Peninsula). This rare bivalve was collected from deep waters (1200 m depth) of the Avilés Canyon Systems (Central Cantabrian Sea). We provide a detailed description and illustration of the species, as well as brief notes on its ecology at the new locality and its global biogeography.

Key words: *Halicardia flexuosa*, flexed verticord, Anomalodesmata, Cantabrian Sea, Iberian Peninsula, biodiversity

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Introduction

Among bivalves, members of the superorder Anomalodesmata (formerly known as Septibranchia) represent one of the most intriguing groups of deep-water mollusks. They have developed a series of anatomical and conchological modifications toward a carnivorous and/or scavenger lifestyle (Morton 1981; Allen & Turner 1974). Anomalodesmatans have modified their gills into a pair of muscular perforated septa that separate the exhalant chamber from the inhalant one. Thus, their reduced branchiae allow the animals to suck in small prey by generating a strong inhalant current and expelling water through the exhalant chamber. In addition to the modified gills, they have developed other adaptations to this peculiar lifestyle, such as a muscular esophagus and a stomach covered by scleroproteins that allows them to crush their food (Allen, Turner 1974). Furthermore, verticordids can release adhesive fluid from inhalant and exhalant siphons, which helps them to capture small prey and maintains their position on the surface of soft sediment (Allen, Turner 1974). This carnivorous strategy seems to work in deep-water ecosystems that are usually deficient in food for filter-feeding bivalves, representing only 10% of the abyssal benthic fauna (Allen & Turner 1974). The distributional pattern of Anomalodesmata is essentially based on members of the family Verticordiidae (Allen & Turner 1974). However, even though verticordids are one of the lesser known groups of contemporary bivalves, due to their rarity and restriction to abyssal depths, they represent a small but persistent fraction of the abyssal benthic fauna (Allen & Turner 1974). It is therefore not surprising that the members of the family Verticordiidae are extremely scarce in the European collections (Poppe & Goto 2000). To date, only four species of the family Verticordiidae have been recorded in the Bay of Biscay: *Laevicordia insculpta* (Seguenza, 1876); *Spinosipella acuticostata* (Philippi, 1844); *Haliris lamothei* (Dautzenberg & H. Fischer, 1897) and *Haliris granulata* (Seguenza, 1860), all collected in deep water (Locard 1898).

Several specimens, conchologically consistent with the diagnosis of the verticordid genus *Halicardia* Dall, 1895, have recently been collected from deep water of the Central Cantabrian Sea (northern Spain). These constitute the first record of the genus from the Bay of Biscay. In this paper we present a detailed description and illustration of the recorded *Halicardia* species, including brief notes on its ecology and distribution at the new locality. Furthermore, we provide an updated review of its global biogeography and habitats.

Materials and results

The taxonomy of the species described herein follows MolluscaBase (2019).

Superorder Anomalodesmata Dall, 1889

Family Verticordiidae Stoliczka, 1870

Halicardia flexuosa (Verrill & S. Smith [in Verrill], 1881)

Material examined: 1 complete specimen, 2 right valves and 1 fragment of another right valve, BIOCANT Station P3 (43°58.01'N – 6°30.95'W), 1200 m depth, sandy bottom, Avilés Canyon Systems

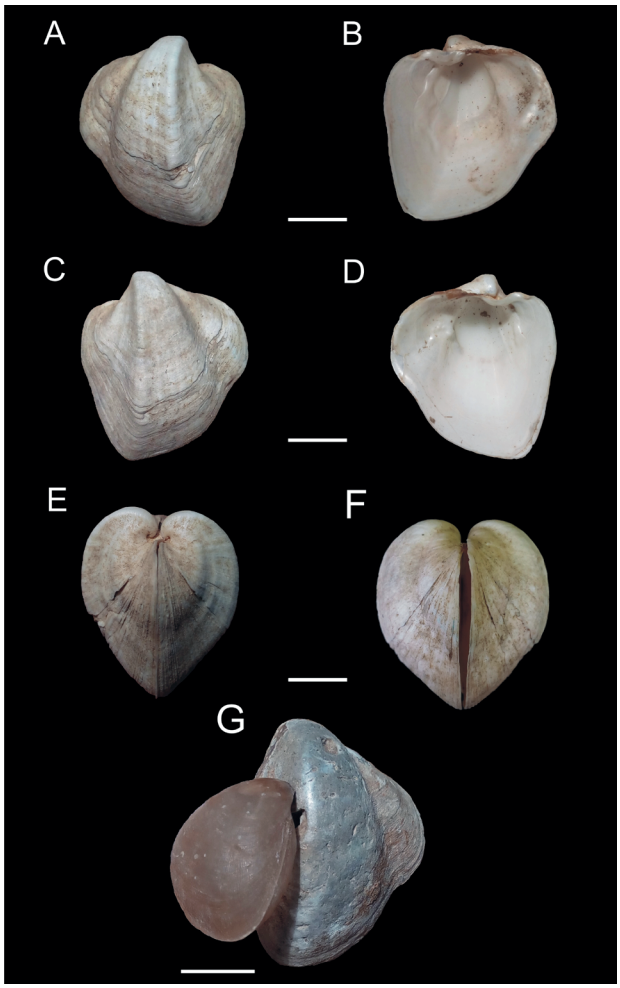

Figure 1

Halicardia flexuosa. A: external view of the left valve; B: internal view of the left valve; C: external view of the right valve; D: internal view of the right valve; E: anterior view; F: posterior view; G: external view of the right valve with the attached brachiopod Hispanirhynchia cornea. All scale bars: 1 cm

(ACS), Cantabrian Sea, Bay of Biscay, 30 April 2013, coll. BIOCANT Oceanographic Cruise. Comparative material: Holotype (USNM 46129), several photographs, complete specimen, Martha's Vineyard Island, 570 m depth, sandy-muddy bottom, Massachusetts, northwest Atlantic Ocean, 9 Aug. 1881, coll. United States Fish Commission.

Description: Large species, max width of ~3.90 cm; max height of 4.50 cm (Dall 1895); Cantabrian specimens ranging in width from 3.05 to 3.20 cm, with a mean of 3.15 cm (N = 3) and in height from 3.4 to 3.65 cm, with a mean of 3.55 cm (N = 3). Wide, short and angular shell, higher than longer, with rounded and trapeziform outlines (Fig. 1A–D; Fig. 2); posterior end larger than the anterior one. Umbones very prominent, anteriorly curved. Triangular and depressed lunule; sublunular tooth fainter in the left valve. Shell whitish-brown with granulated surface and full of bends (very flexuous, explaining its specific name *flexuosa*). Anterior area with a slightly concave medial depression; central area very elevated with a conspicuous, broadly rounded and slightly curved rib, crossing the shell from umbo to ventral margin. Posterior area lacking ribs, bearing a prominent rounded edge and separated from the central rib by a concave furrow. Interior of the shell nacreous (Fig. 1B, D) with a deep concave furrow; hinge-line straight in posterior area, curved in the anterior one and projected inward only in the right valve; small tubercle in the right valve. Lithodesma not present in Cantabrian specimens nor holotype, but according to Verrill & Smith (1881), the right arm commonly longer than the left one. Anterior adductor muscle scar deep; posterior muscle scar ovoid-shaped and larger than the anterior one. Pallial sinus small. Membrane connecting gill filaments to the mantle and foot present. Length of gills greatly reduced.

Remarks: This species was originally described by Verrill & S. Smith in Verrill (1881) as *Mytilimeria flexuosa* from deep water in Massachusetts. Shortly thereafter, Dall (1889) transferred the species to the genus *Verticordia* and reported it again from the coasts of Massachusetts and, for the first time, from New Jersey as *Verticordia flexuosa*. Some years later, the former author erected a new genus for this bivalve, i.e. *Halicardia*, designating *H. flexuosa* as the type species (Dall 1895). This new genus was characterized by a swollen and large shell with several ribs and deep or shallow furrows and depressions, granulated surface, small and slight lunule, hinge plate feeble, cardinal tooth almost inconspicuous in the right valve and opisthopodium posterior to the foot in the visceral mass.

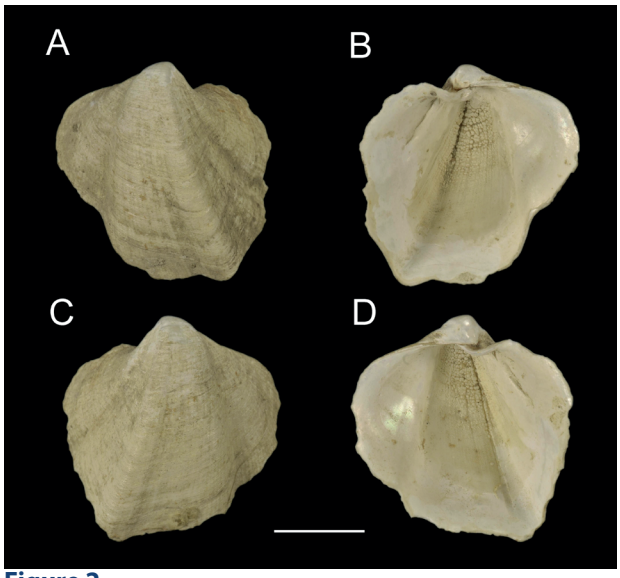

Figure 2

Holotype of *Mytilimeria flexuosa* Verrill & S. Smith, 1881 (= *Halicardia flexuosa* (Verrill & S. Smith [in Verrill], 1881)). A: external view of the left valve; B: internal view of the left valve; C: external view of the right valve; D: internal view of the right valve. Scale bar: 1 cm. Adapted from the Smithsonian Institution, National Museum of Natural History

Habitat and ecology: Cantabrian specimens were collected using an Agassiz dredge in sandy seabed from a depth of 1200 m, within the boundaries of the Avilés Canyon System, a Site of Community Importance (SCI) included in the Natura 2000 Network. The sampling station was located in an area with the presence of deep-sea coral reefs, which are protected under the European Union Habitats Directive (Habitat 1170: Directive habitats 92/43/CEE). One live specimen of the brachiopod *Hispanirhynchia cornea* (Fischer in Davidson, 1886) was found attached to one of the empty valves found (Fig. 1G).

Discussion

Historical biogeography of the species (Table 1; Fig. 3): the type locality of *H. flexuosa* is Martha's Vineyard Island (Massachusetts, northwest Atlantic Ocean), at a depth of 570 m in the sandy-muddy substrate. The original description was based on the holotype, a complete specimen represented by a pair of empty valves (Fig. 2; Verrill 1881). Its distribution in the northwest Atlantic Ocean ranges from New Scotland to Canada, from a depth of 570 to 1458 m

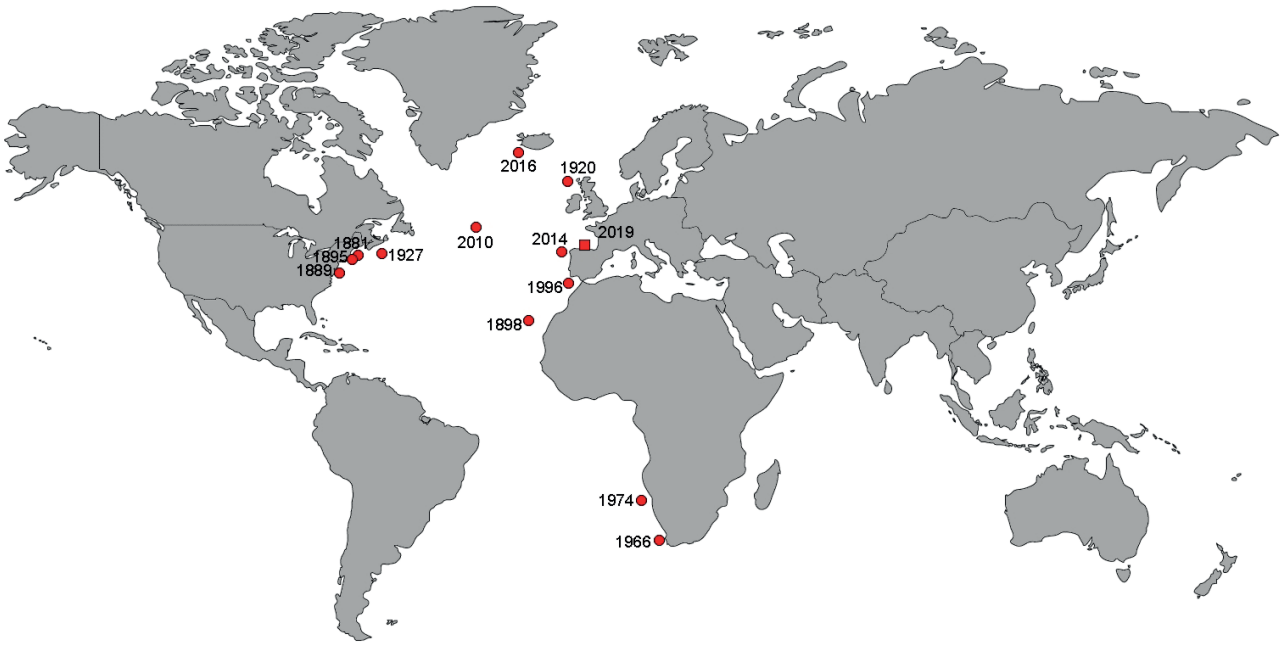

Figure 3

Global distribution map of *Halicardia flexuosa*. Square: locality from the present study; circles: localities from bibliography data. Date of the first record of the species for each locality is included

Table 1

Updated summary of the worldwide records of *Halicardia flexuosa*

Locality	Coordinates	Year	Ocean	Cruise	Sampling method	Depth (m)	Substrate	Nº Ind.	Reference
Martha's Vineyard (Massachusetts)	n/a	1881	NW Atlantic	U.S. Fish Commission	rake-dredge	570	sand/mud	2 valves	Verrill 1881
Cabo Blanco (Sahara)	n/a	1883	NE Atlantic	Talisman	n/a	1495–2300	n/a	3 fresh specimens + 1 valve	Locard 1898
Gulf of Maine	n/a	1885	NW Atlantic	Albatross/U.S. Fish Commission	n/a	1238	brown sand	1 dead specimen	Dall 1895
West coast of Scotland	57°41'N; 11°48'W	1910	NE Atlantic	Michael Sars' North Atlantic	n/a	1853	n/a	n/a	Grieg 1920
New Scotland	42°40'N; 62°49'30''W	1913	NW Atlantic	Prince de Monaco	trawling	1458	n/a	2 valves	Dautzenberg 1927
Namibia	23°00'S; 12°45'E	?1968	SE Atlantic	Atlantis II	n/a	1007–1014	n/a	1 ?dead specimen	Allen & Turner 1974
Cape St. Vincent (South Iberian Peninsula)	36°45'N; 9°32'W	1984	NE Atlantic	Balgim Expedition	n/a	1592	ooze?	1 ?fresh specimen	Salas 1996
Charlie-Gibbs Fracture Zone	52°58'N; 34°52'W	2004	Mid Atlantic	G.O. Sars MAR-ECO cruise	trawling	1650	n/a	1 ?fresh specimen	Gebruk et al. 2010
Galician Bank (NW Spain)	n/a	2010–2011	NE Atlantic	INDEMARES	Bou de Vara/GOC	1720	soft	n/a	IEO* 2014
Avilés Canyon System (central Cantabrian Sea)	43°58.01'N; 6°30.95'W	2013	NE Atlantic	BIOCANT cruise	Agassiz dredge	1200	sand	1 fresh specimen + 3 valves	Present paper
SW Iceland	63°05.67'N; 26°52.12'W and 63°08.67'N; 26°52.92'W	2015	NE Atlantic	R/V Árni Fridricksson	trawling	1281–1300	clay	2 fresh specimens + some loose valves	Delongueville et al. 2016
Rhode Island (Massachusetts)	41°13'N; 66°19.83'W	n/a	NW Atlantic	n/a	n/a	137–1210	n/a	1 valve	Dall 1889
Cape Point (South Africa)	n/a	n/a	SE Atlantic	Pieter Faure	n/a	840–1188	n/a	some valves	Soot-Ryen 1966

n/a: not available. *IEO: Spanish Institute of Oceanography

(Verrill 1881; Dall 1889; Dall 1895; Dautzenberg 1927). It was also reported from the northwest area of the Charly-Gibbs Fracture Zone (North Atlantic Ocean) at a depth of 1650 m (Gebruk et al. 2010). On the other side of the Atlantic (northeast Atlantic Ocean), *H. flexuosa* was reported from a depth of 840 to 2330 m. The species was first collected in 1883 from the deep-sea waters of Cape Blanc (Sahara) during the Talisman cruises (Locard 1898) and was not found again until the decade of 1910 (Grieg 1920; Soot-Ryen 1966). Nearly 30 years later, it was reported from the west coast of Scotland during the "Michael Sars" North Atlantic deep-sea expedition (Grieg 1920) and from Cape Point (South Africa; Soot-Ryen 1966). During the last 20 years, *H. flexuosa* has been reported from four further localities of the NE Atlantic (Salas 1996; Gebruk et al. 2010; De la Torriente et al. 2014; Delongueville et al. 2016), but the findings have always consisted of a few specimens, which in most cases were incomplete empty valves (see Table 1).

The species has recently been reported from the Galician Bank (Iberian Peninsula; De la Torriente et al. 2014; Gofas et al. 2017), the southwest coasts of Iceland (Delongueville et al. 2016) and is herein described from the Avilés Canyon System, which constitutes the first record of the species from the Cantabrian Sea and the Bay of Biscay (Fig. 3; Table 1). This report increases the total number of verticordid species recorded in the Bay of Biscay to five and stresses the need for intensified research and monitoring efforts aimed at understanding the diversity and distribution of deep-water bivalves that inhabit the European waters.

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