

## Article

# Deep-Sea Ophiuroids (Echinodermata; Ophiuroidea) from the Avilés Canyon System: Seven New Records for the Spanish North Atlantic Marine Subdivision

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**Abstract:** The Avilés Canyon System (ACS) is located in the southern Bay of Biscay (northern Spain, Cantabrian Sea). It has been declared a Site of Community Importance (SCI: C ESZZ12003) within the Natura 2000 Network and recognized as a Vulnerable Marine Ecosystem (VME). This area is included in the North Atlantic Marine Subdivision (NAMD). The present study reviews ophiuroid fauna collected during the INDEMARES–ACS project and compares the new findings with previous studies using the Official Spanish Checklist (“Inventario Español de Especies Marinas”) to update our knowledge on the diversity and distribution of these species. During the surveys carried out within the LIFE + INDEMARES–Avilés Canyon System project (2010–2012), a total of 7413 specimens belonging to 45 ophiuroid species were collected from 50 stations in a depth range between 266 and 2291 m. The most frequent species was *Ophiactis abyssicola* (M. Sars, 1861). Comparing the identified species with public datasets, seven species should be considered as new records for NAMD: *Ophiocent centobi* Paterson, Tyler & Gage, 1982, *Amphiura borealis* (G.O. Sars, 1872), *Amphiura fragilis* Verrill, 1885, *Ophiochondrus armatus* (Koehler, 1907), *Ophiosabine parvita* (Koehler, 1906), *Ophiophrinx spinosus* (Storm, 1881), *Ophiotreta valenciennesi* (Lyman, 1879). Furthermore, one species has expanded its bathymetric range: *Ophiosabine parvita* (Koehler, 1906).

**Keywords:** checklist; Bay of Biscay; INDEMARES; NAMD

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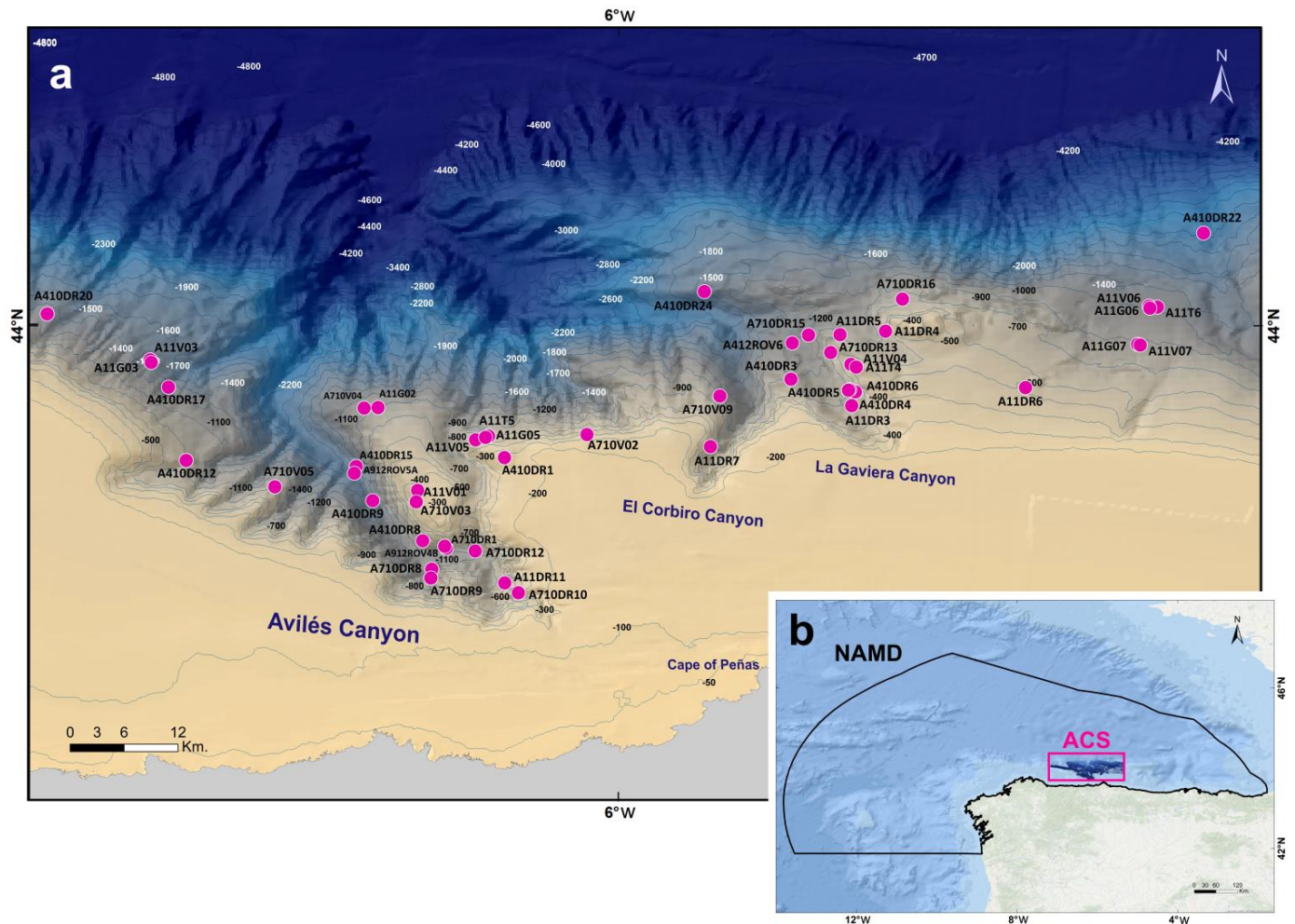


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## 1. Introduction

The Avilés Canyon System (ACS) (Figure 1a) (43.87° N and –6.10° W) begins on the continental slope of the southern edge of the Bay of Biscay in the Cantabrian Sea (Northeast Atlantic Ocean) and is part of the Spanish Exclusive Economic Zone (ZEE: [1]) and of the North Atlantic Marine Subdivision (NAMD) (Figure 1b) [2]. It is made up of three main canyons Avilés, El Corbiro and La Gaviera, with a total extension of 3390 km<sup>2</sup> [1,3,4]. The ACS was declared by the Ministry of Agriculture, Food and Environment of Spain [5] (2014) a Site of Community Importance (SCI: C ESZZ12003) within the framework of the Natura 2000 Network [6,7] and recognized as a vulnerable marine ecosystem (VME: following the OSPAR Convention for the Protection of the Marine Environment of the Northeast Atlantic (<https://www.ospar.org/convention/text>, accessed on 9 January 2024) in whose communities and habitats echinoderms play a significant role.

The area is influenced by water masses of different origins: Eastern North Atlantic Central Water (ENACW), Labrador Sea Water (LSW), North Atlantic Deep Water (NAWD) (the deepest and coldest) and Mediterranean water (MW) that reaches the Bay of Biscay through the Strait of Gibraltar. In addition, the area also receives water from the Caribbean and the Gulf Stream (warm and shallow). Therefore, the marine species of the Cantabrian Sea could have different biogeographic origins [8].



**Figure 1.** (a) Area of study. Main canyons and sampling stations with presence of ophiuroids. (b) Location of the North Atlantic Marine Subdivision (NAMD) and the ACS.

Thanks to the geomorphology of the area and local currents, the study area is rich in nutrients at different depths [1]. This makes the ACS a favorable place for the settlement of benthic communities [1,9–11].

Previous taxonomic works on ophiuroids in this area were published by several authors in the late 19th and the 20th centuries. Their studies were carried out on the shelf at the limit of the slope, but rarely in the canyons: [12,13] (*H.M.S. Challenger*); [14–16] (*Travailleur* and *Talisman*); [17,18] (Caudan); [19–23] (*Princesse Alice*; and *Hirondelle*); [24] (Huxley); [25] (Michael Sars); [26] (Danish Ingolf Expedition); [27] (*Thalassa*); [28] (*Norat-lante*); [29] (*Hespérides 76*); [30] (*Biogas*); and [31] (*Cantábrico 83*).

Recently, other expeditions have been undertaken with different approaches (fisheries, ecological and/or protected areas management), such as [32] (COFACE), [1] (LIFE + INDEMARES–ACS), and [33] (ECOMARG, LIFE + INDEMARES–ACS and SponGES), in which the Spanish Echinoderms Laboratory of the University of Málaga (SELUMA) has been involved, giving us the opportunity to study the ophiuroid communities at depths barely sampled before in the ACS.

## 2. Material and Methods

### 2.1. Sampling

LIFE + INDEMARES–ACS surveys consisted of five multidisciplinary surveys (2010–2012), aboard four different vessels (*Vizconde de Eza*, *Thalassa*, *Ramon Margalef* and *Angeles Alvarriño*). This study includes ophiuroids collected at a total of 50 stations within a depth

range between 266 m and 2291 m (from the beginning of the continental slope to the maximum depth sampled in the bathyal zone (Table 1, Figure 1a) using multiple kinds of equipment (Table 1).

**Table 1.** Geographical positions and depth of sampled stations. ST: station, LAT: latitude (decimal degrees), LON: longitude (decimal degrees), D: depth (m). Below: Data of samplers.

ST	LAT	LON	D	ST	LAT	LON	D
A11DR11	43.74	−6.11	560	A410DR20	44.01	−6.57	1387
A11DR3	43.92	−5.77	776	A410DR22	44.09	−5.41	2291
A11DR4	43.99	−5.73	593	A410DR24	44.03	−5.91	1533
A11DR5	43.99	−5.78	908	A410DR3	43.95	−5.83	893
A11DR6	43.94	−5.59	462	A410DR4	43.93	−5.76	700
A11DR7	43.88	−5.91	551	A410DR5	43.93	−5.77	688
A11G02	43.92	−6.25	1051	A410DR6	43.93	−5.77	790
A11G03	43.96	−6.47	1464	A410DR8	43.78	−6.20	844
A11G05	43.89	−6.13	578	A410DR9	43.82	−6.25	1513
A11G06	44.02	−5.46	1244	A412ROV6	43.98	−5.83	1161
A11G07	43.98	−5.48	990	A710DR1	43.78	−6.17	810
A11T4	43.96	−5.77	530	A710DR10	43.73	−6.10	342
A11T5	43.88	−6.14	538	A710DR12	43.78	−6.14	843
A11T6	44.02	−5.47	1238	A710DR13	43.97	−5.79	769
A11V01	43.83	−6.20	355	A710DR15	43.99	−5.81	1228
A11V03	43.96	−6.47	1473	A710DR16	44.03	−5.71	928
A11V04	43.96	−5.76	510	A710DR8	43.76	−6.19	800
A11V05	43.89	−6.13	552	A710DR9	43.75	−6.19	626
A11V06	44.02	−5.47	1228	A710V02	43.89	−6.03	401
A11V07	43.98	−5.48	984	A710V03	43.82	−6.20	357
A410DR1	43.87	−6.11	266	A710V04	43.92	−6.24	1015
A410DR12	43.86	−6.43	828	A710V05	43.84	−6.34	783
A410DR15	43.86	−6.26	1660	A710V09	43.93	−5.90	930
A410DR17	43.94	−6.45	1476	A912ROV4B	43.78	−6.17	942
A410DR19	43.96	−6.60	533	A912ROV5A	43.85	−6.26	1576
SAMPLER	WIDTH (m)	HEIGHT (m)	MESH SIZE (mm)	SPEED (knots)	SAMPLING TIME (min)	SAMPLED AREA (m <sup>2</sup> )	
Rock dredge (DR)	0.8	0.3	10	1.5	5	183.71	
Bou de vara (V)	3.5	0.65	10	2	15	3241	
Beam trawl (GOC-73)	19.44	2.68	10	3	30	54,004.32	
Supra-benthic sledge (TS)	-	0.9	5	1.5	3	≈500	

## 2.2. Systematics

Ophiuroids were sorted and fixed in 70% ethanol, and their identification was based on morphological characters according to Koehler [34], Fell [35], D'yakonov [36], Matsumoto [37], Mortensen [38] and Paterson [39,40], among others. All taxon names were checked for relevance and synonymies based on the original descriptions. Ophiuroid classification was checked in the World Register of Marine Species (WoRMS, accessed on 9 January 2024), and AphiaIDs (urn:lsid:marinespecies.org:taxname) [41] were included in new records of species as a link to synonymies. For morphological notations, it followed Paterson [40].

New records were compared to the known distribution of species using the Official Spanish Checklist (IEEM: “Inventario Español de Especies Marinas”. Ophiuroidea: [42,43]) related to the NAMD and supported by other open-access databases: GBIF [44], Muséum National d’Histoire Naturelle [45] (accessed on 9 January 2024), OBIS [46] and the USNM Invertebrate Zoology Collection (Smithsonian National Museum of Natural History, [47] accessed on 9 January 2024).

### 3. Results

A total of 7413 specimens, which correspond to 45 species, were collected (see Table 2). The most abundant species (number of specimens) were *Ophiocten affinis* (Lütken, 1858) with 4092 specimens and *Ophiothamnus affinis* Ljungman, 1872 with a total of 1842 specimens. The most frequent one (occurrence by station in which the species is present) was *Ophiactis abyssicola* (M. Sars, 1861), present in 24 of 50 stations. Comparing our species with public databases (OBIS and GBIF accessed on 9 January 2024) and the bibliography, seven new records were found for the Cantabrian Sea (NAMD) of which one also expands its bathymetric range: *Ophiosabine parvita* (Koehler, 1906). Species diagnoses of new records are described below. Illustrations of historical distribution areas and new records at ACS are included in Figures beneath.

#### Order Ophiurida

#### Family Ophiuridae

*Ophiocten centobi* Paterson, Tyler & Gage, 1982

AphiaID: 124852

Material examined: 1 preserved specimen from station A410DR17.

Diagnostic characters: Disk round with centrodorsal and primary plates very large and conspicuous, separated by a thin row of small plates (Figure 2a). Twice broader than long radial shields, contiguous (Figure 2e). Arm comb with stout, pointed and continuous papillae over the arm base (Figure 2e). Large plates in the ventral interradial area (Figure 2b). Slightly arched, fan shaped and contiguous dorsal arm plates (without spinelets on the distal edge) (Figure 2f). Separated ventral arm plates with distal rounded edge and acute proximally (Figure 2g). Up to 3 tentacle scales proximally, decreasing distally. Three-pointed arm spines (the dorsalmost is the longest) (Figure 2h). One pointed oral papilla, from 3 to 4 oral papillae (pointed proximally and block-like distally). Pentagonal oral shield with rounded distal edge (sometimes with slightly lateral projections) (Figure 2d). Conspicuous genital slit wholly lined by a row of stout and pointed papillae (Figure 2c).

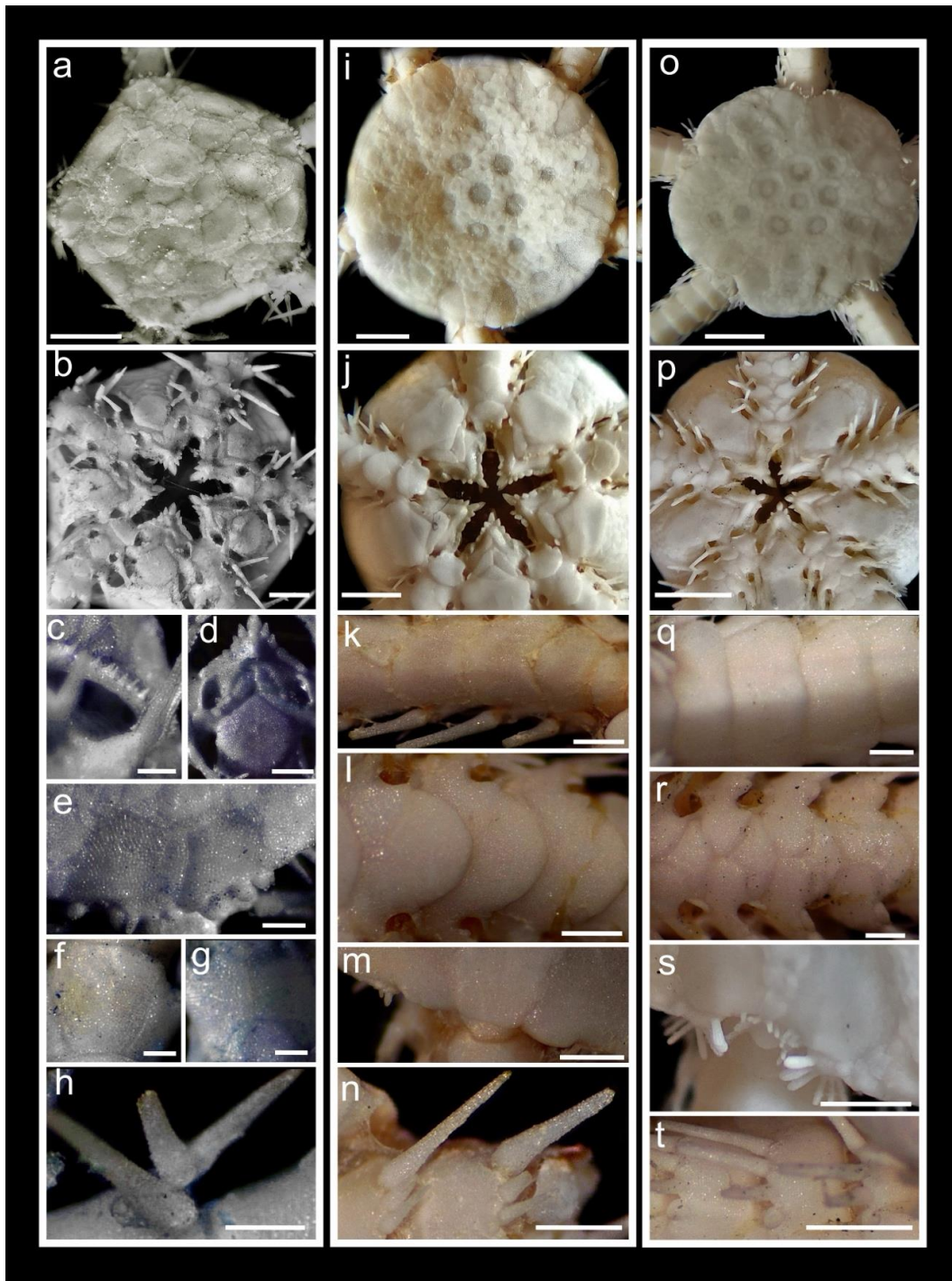
Distribution: North Atlantic Ocean, Mid-Atlantic Ridge, north of the Bay of Biscay, off the coast of New York (Figure 3I).

Bathymetric range: 400 m [48]–2837 m (Stöhr, S. (MNHN) [45]). Present study: 1476 m.

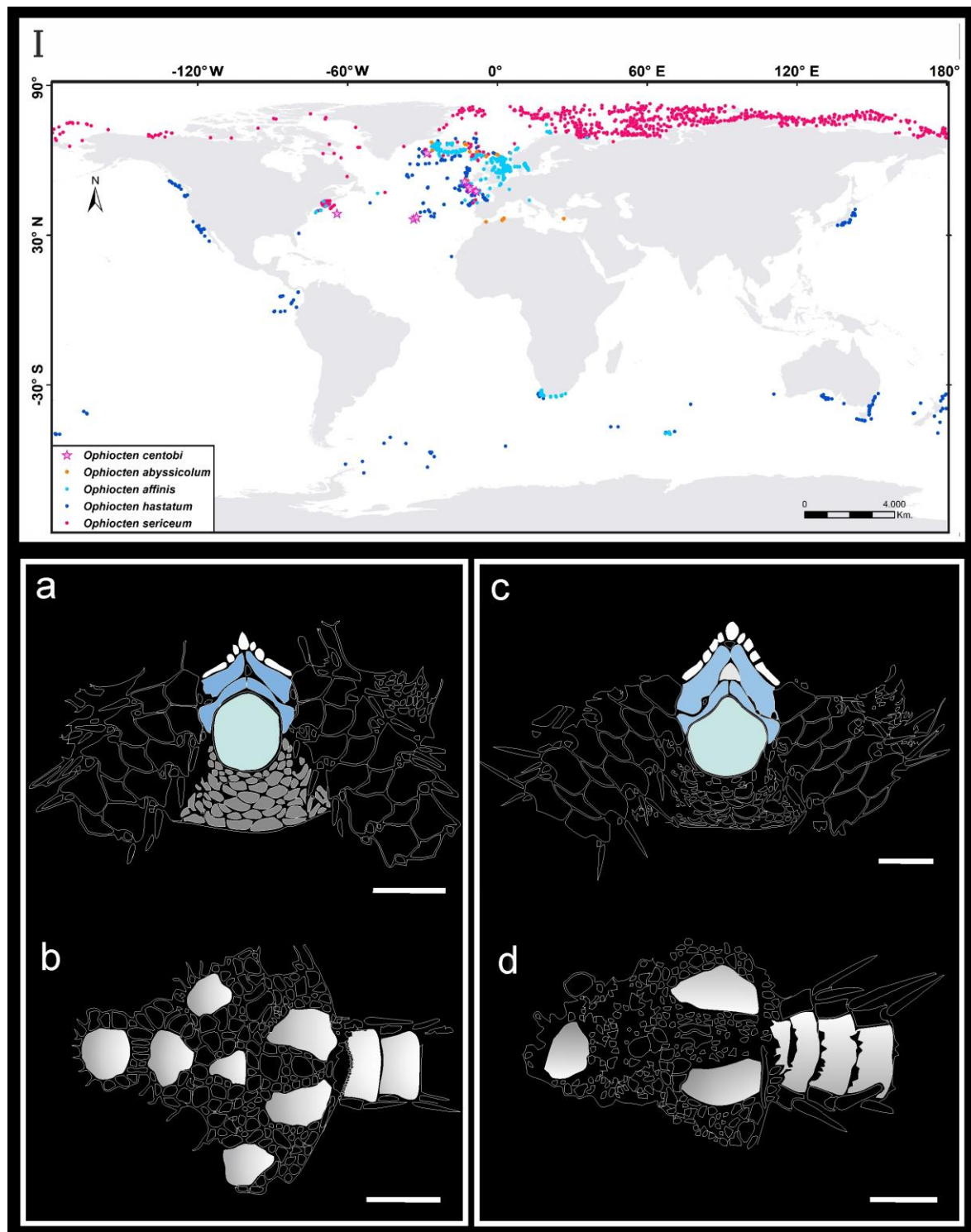
Remarks: Of the 5 *Ophiocten* species present in the NAMD (Figure 2a–t; Figure 3a–d), *O. centobi* is distinguished from *O. hastatum* because the latter does not have a developed arm comb (Figure 2m) and due to the very short oral shield (not reaching the first arm vertebra) (Figure 2j); from *O. affinis* due to the length and shape of the arm comb papillae, short, thick and contiguous in *O. centobi* (Figure 2e) and long, spiniform and with a double comb in *O. affinis* (Figure 2s). Furthermore, the oral shield of *O. affinis* is much longer than the oral shield of the rest of the species (Figure 2p). *Ophiocten centobi* can be clearly distinguished from *Ophiocten sericeum* (Forbes, 1852) by the size of the disk plates, larger in *O. centobi* (Figure 2a) and very small in *O. sericeum* (Figure 3d), and the presence of papillae on the dorsal proximal plates of the arm of *O. sericeum* (Figure 3d). Finally, it can be distinguished from *Ophiocten abyssicolum* (Forbes, 1843) because its dorsal plates are strongly arched, rectangular and much wider than long; in addition, the first plate may have papillae (Figure 3b), while in *O. centobi* they are fan-shaped and may be slightly arched (Figure 2f).

Table 2. Taxonomic classification of the species sampled in ACS.

Order	Family	Scientific Name and Authority	
<b>Euryalida</b> Lamarck, 1816	<b>Asteronychidae</b> Ljungman, 1867	<i>Asteronyx loveni</i> Müller & Troschel, 1842	
	<b>Euryalidae</b> Gray, 1840	<i>Asteroschema inornatum</i> Koehler, 1906	
<b>Ophiurida</b> Müller & Troschel, 1840 sensu O'Hara et al., 2017	<b>Ophiomusaidae</b> O'Hara, Stöhr, Hugall, Thuy & Martynov, 2018	<i>Ophiomusa lymani</i> (Wyville Thomson, 1873) <i>Amphiophiura bullata</i> (Thomson, 1877) <i>Ophiopleura inermis</i> (Lyman, 1878) <i>Ophiuroglypha irrorata</i> (Lyman, 1878) <i>Stegophiura macrarthra</i> H.L. Clark, 1915 <i>Ophiocten affinis</i> (Lütken, 1858) <i>Ophiocten centobi</i> Paterson, Tyler & Gage, 1982 <i>Ophiura (Dictenophiura) carnea</i> Lütken, 1858 <i>Ophiura ophiura</i> (Linnaeus, 1758)	
	<b>Ophiopyrgidae</b> Perrier, 1893		
	<b>Ophiuridae</b> Müller & Troschel, 1840		
<b>Amphilepidida</b> O'Hara, Hugall, Thuy, Stöhr & Martynov, 2017	<b>Amphilepididae</b> Matsumoto, 1915	<i>Amphilepis norvegica</i> (Ljungman, 1865) <i>Amphiura (Amphiura) grandisquama</i> Lyman, 1869 <i>Amphiura borealis</i> (G.O. Sars, 1872) <i>Amphiura fragilis</i> Verrill, 1885 <i>Amphiura griegi</i> Mortensen, 1920 <i>Amphiura richardi</i> Koehler, 1896 <i>Ophiactis abyssicola</i> (M. Sars, 1861) <i>Ophiactis balli</i> (W. Thompson, 1840) <i>Ophiactis nidarosiensis</i> Mortensen, 1920 <i>Histampica duplicata</i> (Lyman, 1875) <i>Ophiothamnus affinis</i> Ljungman, 1872 <i>Ophiothrix</i> spp. Müller & Troschel, 1840	
	<b>Amphiuridae</b> Ljungman, 1867		
	<b>Ophiactidae</b> Matsumoto, 1915		
	<b>Ophiothamnidae</b> O'Hara, Stöhr, Hugall, Thuy & Martynov, 2018 <b>Ophiotrichidae</b> Ljungman, 1867		
<b>Ophiacanthida</b> O'Hara, Hugall, Thuy, Stöhr & Martynov, 2017	<b>Ophiacanthidae</b> Ljungman, 1867	<i>Ophiacantha abyssicola</i> G.O. Sars, 1872 <i>Ophiacantha bidentata</i> (Bruzelius, 1805) <i>Ophiacantha crassidens</i> Verrill, 1885 <i>Ophiacantha densa</i> Farran, 1913 <i>Ophiacantha lineata</i> Koehler, 1896 <i>Ophiacantha simulans</i> Koehler, 1895 <i>Ophiacantha smitti</i> Ljungman, 1872 <i>Ophiacantha veterna</i> Koehler, 1907 <i>Ophiochondrus armatus</i> (Koehler, 1907) <i>Ophiolinna bairdi</i> (Lyman, 1883) <i>Ophiomitrella globifera</i> (Koehler, 1895) <i>Ophiosabine aristata</i> (Koehler, 1895) <i>Ophiosabine cuspidata</i> (Lyman, 1878) <i>Ophiosabine notata</i> (Koehler, 1906) <i>Ophiosabine parcita</i> (Koehler, 1906) <i>Ophiophrixus spinosus</i> (Storm, 1881) <i>Ophiotreta valenciennesi</i> (Lyman, 1879) <i>Ophiomyxa serpentaria</i> Lyman, 1883	
	<b>Ophiobyrsideae</b> Matsumoto, 1915		
	<b>Ophiotomidae</b> Paterson, 1985		
	<b>Ophiomyxidae</b> Ljungman, 1867		
	<b>Ophioleucida</b> O'Hara, Hugall, Thuy, Stöhr & Martynov, 2017	<b>Ophiernidae</b> O'Hara, Stöhr, Hugall, Thuy & Martynov, 2018	<i>Ophiernus vallincola</i> Lyman, 1878
	<b>Ophioscolecida</b> O'Hara, Hugall, Thuy, Stöhr & Martynov, 2017	<b>Ophiohelidae</b> Perrier, 1893	<i>Ophiomyces grandis</i> Lyman, 1879 <i>Ophiolycus purpureus</i> (Düben & Koren, 1846) <i>Ophioscolex glacialis</i> Müller & Troschel, 1842
		<b>Ophioscolecidae</b> Lütken, 1869	



**Figure 2.** *Ophiocten centobi*: (ID: 124852) (a) Dorsal view of the disk. Scale bar: 1 mm. (b) Ventral view of the disk. Scale bar: 0.5 mm. (c) Papillae of the genital slit. Scale bar: 0.15 mm. (d) Jaw. Scale bar: 0.25 mm. (e) Radial shields and combs. Scale bar: 0.15 mm. (f) Dorsal arm plate. Scale bar: 0.15 mm. (g) Ventral view of arm plates. Scale bar: 0.15 mm. (h) Arm spines. Scale bar 0.25 mm. *Ophiocten hastatum*: (ID: 124854) (i) Dorsal view of the disk. Scale bar: 1.5 mm. (j) Ventral view of the disk. Scale bar: 1.5 mm. (k) Dorsal arm plates. Scale bar: 0.5 mm. (l) Ventral arm plates. Scale bar: 0.25 mm. (m) Arm combs. Scale bar: 0.25 mm. (n) Arm spines. Scale bar 0.5 mm. *Ophiocten affinis*: (ID: 124850) (o) Dorsal view of the disk. Scale bar: 1.5 mm. (p) Ventral view of the disk. Scale bar: 1.5 mm. (q) Dorsal arm plates. Scale bar: 0.25 mm. (r) Ventral arm plates. Scale bar: 0.25 mm. (s) Arm combs. Scale bar: 0.5 mm. (t) Arm spines. Scale bar 0.5 mm.



**Figure 3.** (I) Species distribution map. *Ophiocten abyssicolum*: (a) Ventral sketch of the disk. (b) Dorsal sketch of the disk. Scale bar: 1 mm. (Adapted and modified from Paterson et al. [39]). *Ophiocten sericeum*: (c) Ventral sketch of the disk. (d) Dorsal sketch of the disk. Scale bar: 1 mm. (Adapted and modified from Paterson et al. [39]).

### Order Amphilepidida

#### Family Amphiuridae

*Amphiura borealis* (G.O. Sars, 1872)

AphiaID: 125071

Material examined: 4 preserved specimens from stations A11T5, A710DR10.

Diagnostic characters: Rounded to subpentagonal disk covered with small scales (naked ventrally), centrodorsal and primary plates inconspicuous. Radial shields three times longer than broad and contiguous only distally (Figure 4a). Block-shaped to conical infradental papillae, first tentacle pore in the mouth slit with a spiniform tentacle scale (Figure 4b). Two small and block-like oral papillae. Adoral shields wing-shaped and separating oral shield from first ventral arm plate (sometimes obscured by skin). Rounded triangular oral shield (Figure 4c). Rounded dorsal arm plates, almost contiguous (Figure 4d). Hexagonal to rectangular ventral arm plates, contiguous (Figure 4b). Large tentacle pores with no tentacle scales (Figure 4e). Four arm spines proximally (Figure 4f), the second ventralmost, flattened with an axe-shaped tip (Figure 4e,f).

Distribution: North Atlantic Ocean, Norway, Faroe Islands, Iceland (Figure 4I).

Bathymetric range: 99 m [48]–878 m (Swedish Museum of Natural History (NRM) Stöhr, S) [48]. Present study: 342 m–538 m.

Remarks: see below in *Amphiura fragilis* remarks

*Amphiura fragilis* Verrill, 1885

AphiaID: 125081

Material examined: 1 preserved specimen from station A710V02.

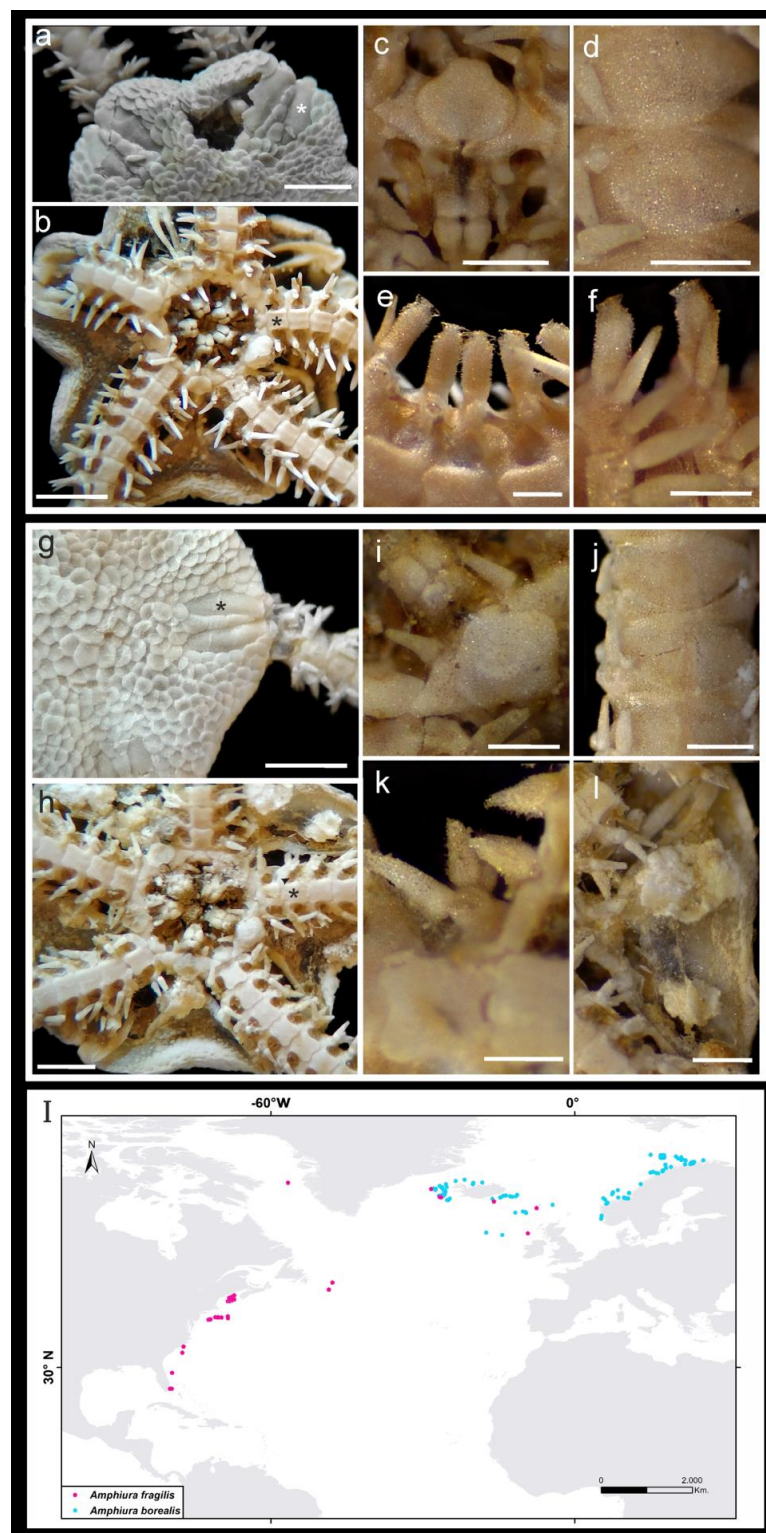
Diagnostic characters: Rounded pentagonal disk, covered by plates. Centrodorsal and primary plates visible in small individuals. Naked ventral area (Figure 4I). Radial shields three times as long as wide and separated (Figure 4g). Dorsal arm plates rounded to hexagonal, not contiguous (Figure 4j). Hexagonal/pentagonal ventral arm plates, contiguous (Figure 4h). Large tentacle pores, with no tentacle scales (Figure 4h). It has 6 to 7 arm spines (4 distally), rough, with serrated and/or hooked ends (Figure 4k). Two infradental papillae, conical (in small individuals) and cubic (in large ones); small, spiny, or scale-shaped oral papilla. Adoral shields wing-shaped. Rounded triangular oral shield, sometimes with a small distal lobe (Figure 4i).

Distribution: North Atlantic Ocean, east coast of USA, Labrador Sea, Iceland, Faroe Islands, north of British Isles (Figure 4I).

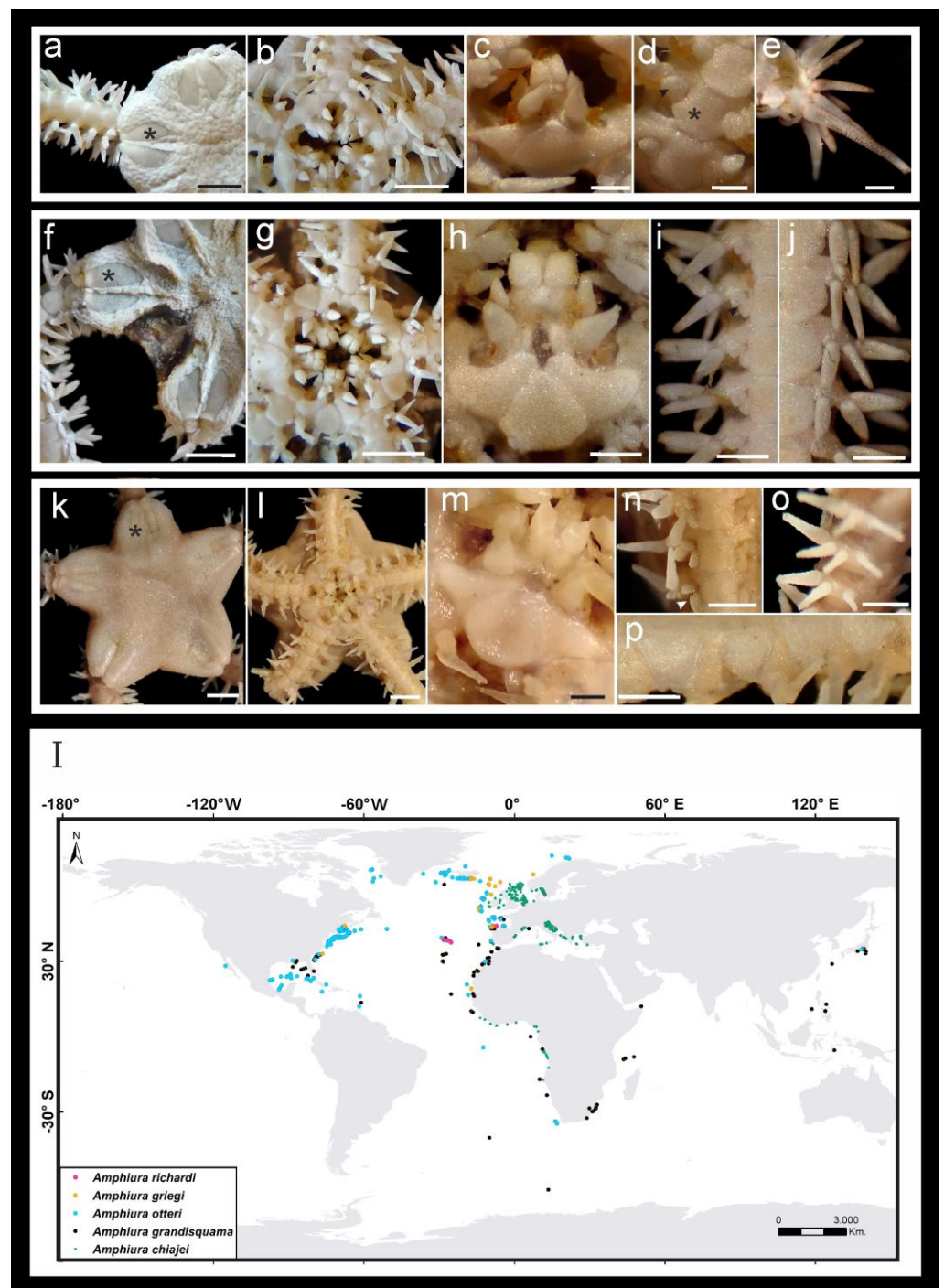
Bathymetric range: 23 m [48]–2683 m [49]. Present study: 401 m.

Remarks *A. fragilis* versus *A. borealis*: Of the 10 species of *Amphiura* previously cited in the NAMD (Figures 5I and 6II), 3 of them have been found at the sampled stations (Figure 1a, Tables 1 and 2) and another 2, *Amphiura chiajei* Forbes, 1843 (Figure 6a–e) and *Amphiura otteri* Ljungman, 1872 (Figure 6f–k), in nearby areas not included in this study. Both *A. fragilis* and *A. borealis* lack tentacle scales in the tentacle pores of the arm (Figure 4b,h) and share this character with the species *Amphiura abyssorum* Norman in Jeffreys, 1876 and *Amphiura filiformis* (O.F. Müller, 1776). The rest of the species have 1 tentacle scale (*A. grandisquama* (Figure 5d)) or 2 (Figure 5i,n and Figure 6c,i). Of those 4 species without tentacle scales, *A. abyssorum* has simple arm spines and the other 3 have modified arm spines. In the case of *A. fragilis*, it has spines that are rough or have serrated edges (Figure 4k), while in *A. borealis* and *A. filiformis* we found 1 or more than 1 (in the case of *A. filiformis*), flattened, rough spines with a hyaline, axe-shaped distal end (Figure 4e,f). Note: all the specimens identified as *A. borealis* have 6 arm spines (Figure 4f), which differs from the original description, but the rest of the characteristics conform to it.

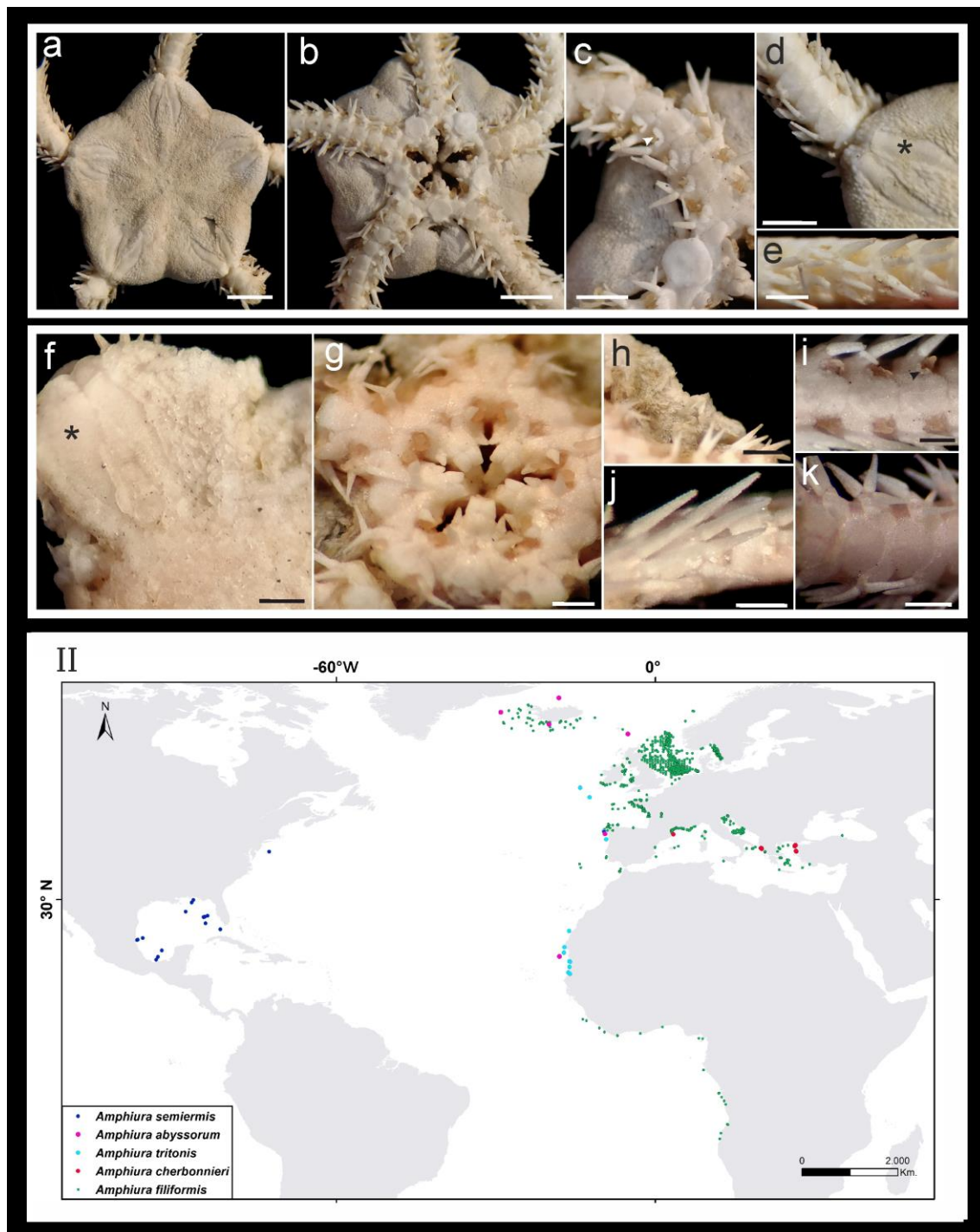




**Figure 4.** *Amphiura borealis*: (ID: 125071) (a) Dorsal view of the disk. \*: Radial shields. Scale bar: 1 mm. (b) Ventral view of the disk. \*: Ventral arm plate. Arrowhead: Absent tentacle scales. Scale bar: 1 mm. (c) Jaw. Scale bar: 0.25 mm. (d) Dorsal arm plates. Scale bar: 0.25 mm. (e) Modified axe-shaped arm spine. Scale bar: 0.25 mm. (f) Arm spines. Scale bar 0.25 mm. *Amphiura fragilis*: (ID: 125081) (g) Dorsal view of the disk. \*: Radial shields. Scale bar: 1 mm. (h) Ventral view of the disk. \*: Ventral arm plate. Arrowhead: Absent tentacle scales. Scale bar: 1 mm. (i) Jaw. Scale bar: 0.25 mm. (j) Dorsal arm plates. Scale bar: 0.25 mm. (k) Rugose arm spines. Scale bar: 0.25 mm. (l) Rugose arm spines. Scale bar: 0.25 mm. (I) Interradial ventral triangle. Scale bar 0.25 mm. (I) Species distribution map.



**Figure 5.** *Amphiura grandisquama*: (ID: 125083) (a) Dorsal view of the disk. \*: Radial shields. Scale bar: 1 mm. (b) Ventral view of the disk. Scale bar: 1 mm. (c) Jaw. Scale bar: 0.25 mm. (d) Ventral arm view. \*: Ventral arm plate. Arrowhead: Tentacle scale. Scale bar: 0.25 mm. (e) Arm spines. Scale bar 0.25 mm. *Amphiura griegi*: (ID: 125084) (f) Dorsal view of the disk. \*: Radial shields. Scale bar: 1 mm. (g) Ventral view of the disk. Scale bar: 1 mm. (h) Jaw. Scale bar: 0.25 mm. (i) Ventral arm view. Arrowhead: Tentacle scales. Scale bar: 0.25 mm. (j) Dorsal arm plates. Scale bar: 0.25 mm. *Amphiura richardi*: (ID: 125094) (k) Dorsal view of the disk. \*: Radial shields. Scale bar: 1 mm. (l) Ventral view of the disk. Scale bar: 1 mm. (m) Jaw. Scale bar: 0.25 mm. (n) Ventral arm view. Arrowhead: Tentacle scales. Scale bar: 0.5 mm. (o) Arm spines. Scale bar 0.5 mm. (p) Dorsal arm plates. Scale bar: 0.5 mm. (I) Species distribution map.



**Figure 6.** *Amphiura chiajei*: (ID: 125073) (a) Dorsal view of the disk. Scale bar: 2 mm. (b) Ventral view of the disk. Scale bar: 2 mm. (c) Jaw. Ventral arm view. Arrowhead: Tentacle scales. Scale bar: 1 mm. (d) Dorsal arm plates. \*: Radial shields. Scale bar: 1 mm. (e) Arm spines. Scale bar: 0.25 mm. *Amphiura otteri*: (ID: 125092) (f) Dorsal view of the disk. \*: Radial shields. Scale bar: 0.25 mm. (g) Ventral view of the disk. Jaw. Scale bar: 0.5 mm. (h) Interradiial ventral triangle. Scale bar: 0.5 mm. (i) Ventral arm view. Arrowhead: Tentacle scales. Scale bar: 0.25 mm. (j) Arm spines. Scale bar: 0.25 mm. (k) Dorsal arm plates. Scale bar: 0.25 mm. (II) Species distribution map (part II).

**Order Ophiacanthida**  
**Family Ophiacanthidae**

***Ophiochondrus armatus* (Koehler, 1907)**

AphiaID: 125016

Material examined: 15 preserved specimens from stations A11DR5, A410DR8, A412ROV6.

Diagnostic characters: Rounded disk, excavated in the interradial area, covered with small plates, each carrying a short, thick and rugose-tipped spinelet on the dorsal side (Figure 7a). Protrusive radial shields rib-shaped, long and narrow and more evident at the edges (Figure 7b). Wide genital slits (Figure 7d). One thick apical papilla flanked by 3–4 thin, conical and pointed oral papillae. Small rounded/triangular oral shield, broader than long. Large, thick and short adoral shield (Figure 7f). Contiguous dorsal arm plates divided by a transversal furrow, small and square proximal portion and fan-shaped and large distal one (Figure 7c). First ventral arm plates longer than broad and hexagonal, next ones slightly pentagonal, longer than broad and contiguous, without tentacle scales in tentacle pores (Figure 7e). Five short arm spines, the dorsalmost with the greater length (Figure 7g).

Distribution: North Atlantic Ocean, Florida, Azores (Figure 7I).

Bathymetric range: 230 m [48]–1250 m [21]. Present study: 844 m–1161 m.

Remarks: *Ophiochondrus armatus* is easily distinguished from the other species of the genus by the dorsal arm plates, divided transversely in the case of *O. armatus* (Figure 7c) and simple in the rest of the species (Figure 7II). Paterson [40] also found a similarity with the species *Ophiolebes resecta* (Koehler, 1895) since they share the characteristic of transversely divided dorsal arm plates and a similar jaw and radial shields. But the ornamentation of the disk in *O. resecta* comprises low granules, while in *O. armatus* it comprises spinelets with a rugose tip. Furthermore, the dorsal arm plates of *O. armatus* are contiguous, and in *O. resecta* they are separated. Note: *Ophiochondrus armatus* specimens found have up to 7 arm spines (Figure 7g) instead of the 5 arm spines described above. ***Ophiosabine parcita* (Koehler, 1906)**

AphiaID: 1574975

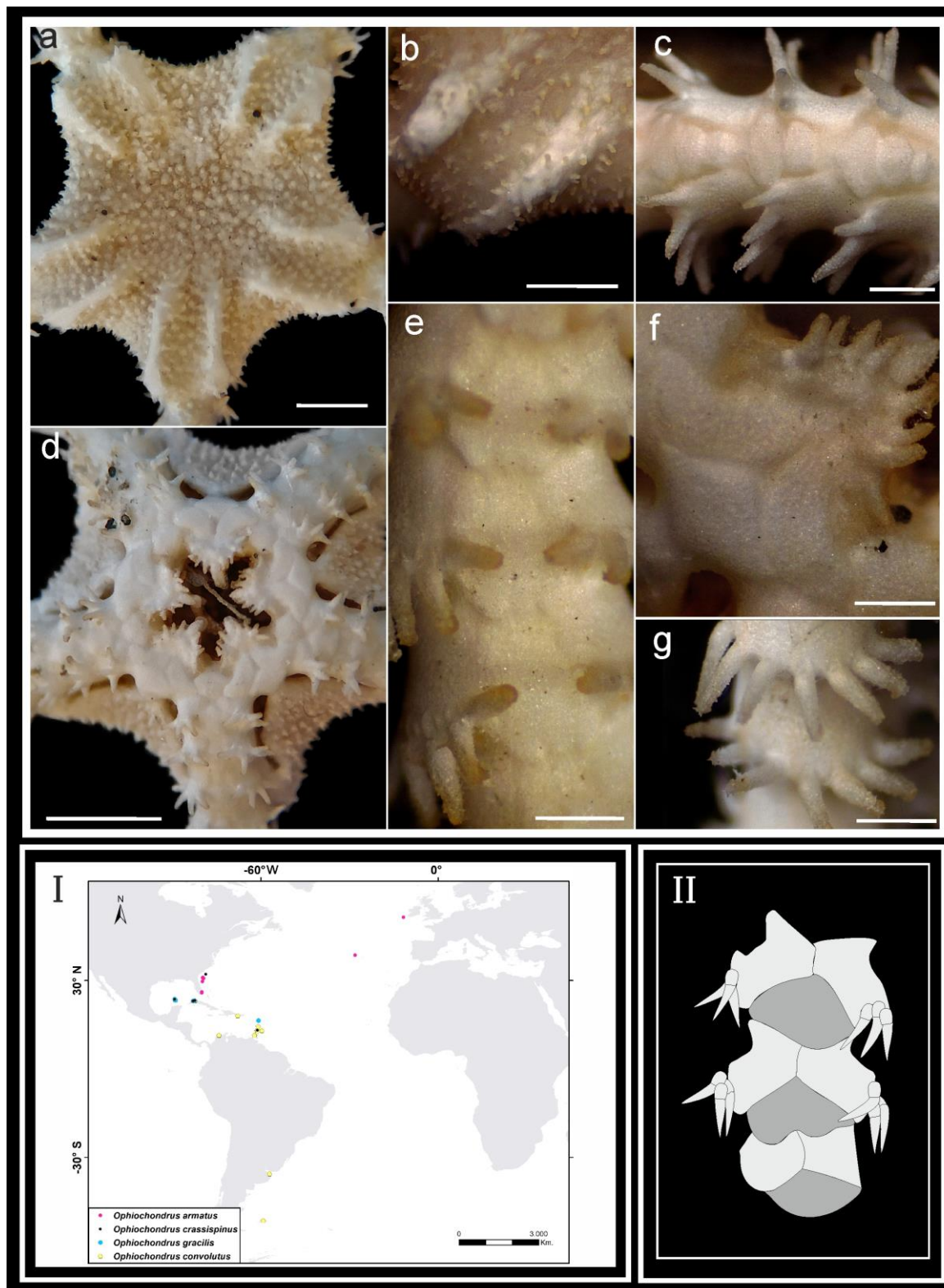
Material examined: 10 preserved specimens from station A410DR17.

Diagnostic characters: Round disk covered by simple spinelets (Figure 8w) with a multipointed crown (up to 8 points) (Figure 8z<sub>2</sub>). Visible radial shields in some specimens. Ventral interradial areas also with spinelets (Figure 8x). One pointed apical papilla flanked by 3 oral papillae, the distalmost enlarged. Distinct oral shield with a rounded proximal edge and a convex distal one, rounded with a slight projection (Figure 8z<sub>3</sub>). Wide and slightly flattened arms. Triangular dorsal arm plates and almost contiguous proximally (Figure 8z<sub>1</sub>). Short pentagonal ventral arm plates, contiguous proximally (Figure 8y, \*). Lateral and ventral arm plates with transverse ridges. One rounded flat tentacle scale in each tentacle pore. Up to 10 arm spines, short and slightly rugose (Figure 8z).

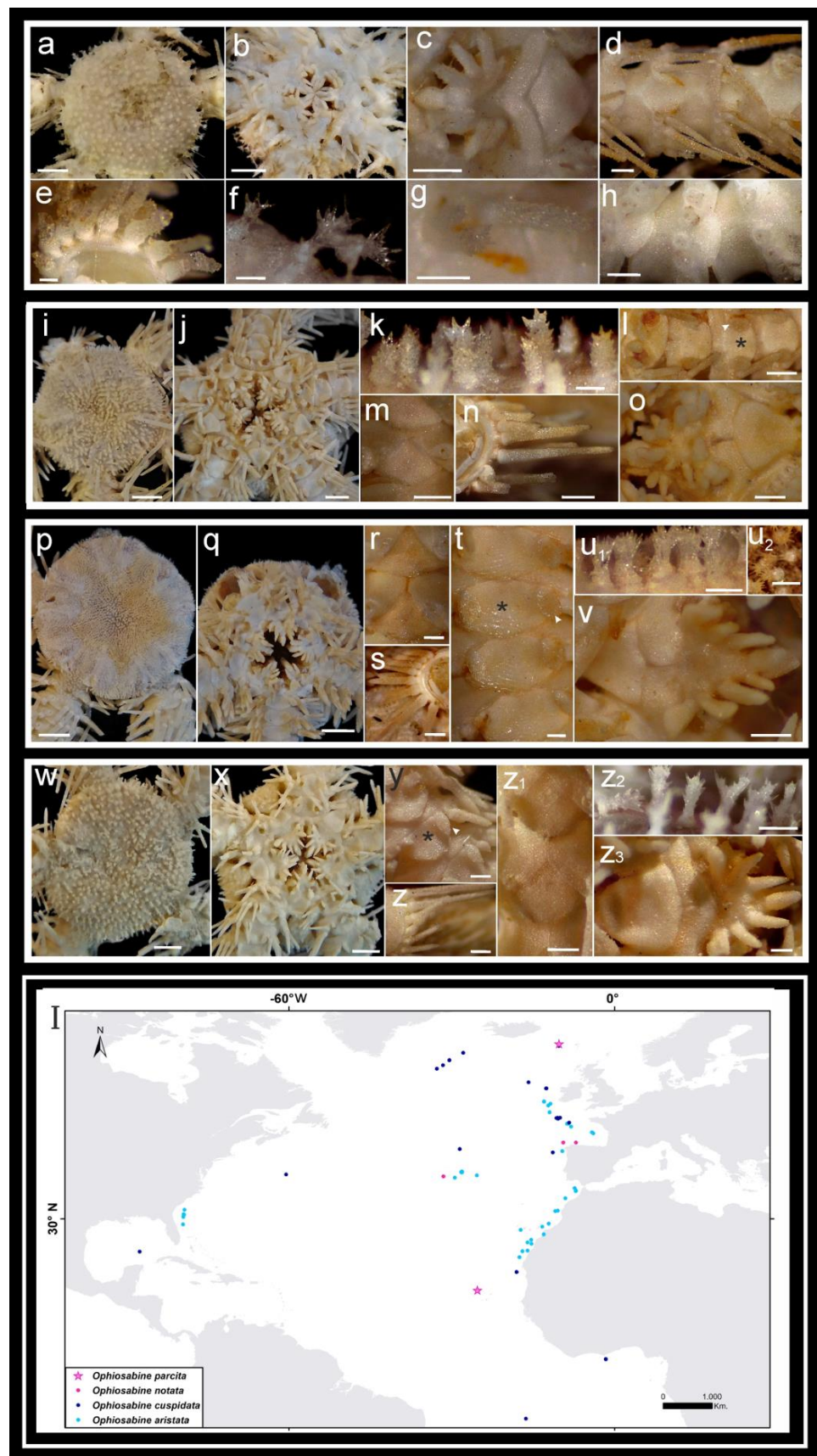
Distribution: North Atlantic Ocean, Cape Verde, near Faroe Islands (Figure 8I).

Bathymetric range: 615 m [15]–749 m [50]. Present study: 1476 m.

Remarks: We have found 4 species of *Ophiosabine* (Figure 8a–z<sub>3</sub>). Of these 4, including both *O. notata* (Figure 8t) and *O. parcita* (Figure 8y), have striations on the ventral and lateral plates of the arm. But they differ in the shape of the disk spinelets, with a wider crown and more points (Figure 8u<sub>1</sub>,u<sub>2</sub>) in the case of *O. notata*, compared to *O. parcita* (Figure 8z<sub>2</sub>) with a narrower crown and up to 8 points. They also differ in the shape of the oral shield, with a proximal obtuse edge and a convex distal edge in the case of *O. notata* (Figure 8v) and rounded proximally with a distal projection in the case of *O. parcita* (Figure 8z<sub>3</sub>). Furthermore, the adoral shields in *O. parcita* are short and almost form a right angle between them and the oral shield (Figure 8z<sub>3</sub>), while in *O. notata* they have a slight wing shape and a pointed distal end (Figure 8v).



**Figure 7.** *Ophiochondrus armatus*: (ID: 1574975) (a) Dorsal view of the disk. Scale bar: 1.5 mm. (b) Radial shields. Scale bar: 0.75 mm. (c) Dorsal arm plates. Scale bar: 0.5 mm. (d) Ventral view of the disk. Scale bar: 2 mm. (e) Ventral view of the arm. Scale bar: 0.5 mm. (f) Jaw. Scale bar: 0.5 mm. (g) Arm spines. Scale bar: 0.5 mm. (I) Species distribution map. (II) Dorsal arm plates of *Ophiochondrus crassispinus* Lyman, 1883. (Adapted and modified from Lyman [51]).



**Figure 8.** *Ophiosabine aristata*: (ID: 1574968) (a) Dorsal view of the disk. Scale bar: 1 mm. (b) Ventral view of the disk. Scale bar: 1 mm. (c) Jaw. Scale bar: 0.25 mm. (d) Ventral view of the arm. Scale bar:

0.25 mm. (e) Arm spines. Scale bar 0.1 mm. (f) Disk ornament spinelets. Scale bar: 0.1 mm. (g) Tentacle scale. Scale bar: 0.2 mm. (h) Dorsal arm plates. Scale bar: 0.25 mm. *Ophiosabine cuspidata*: (ID: 1574970) (i) Dorsal view of the disk. Scale bar: 2 mm. (j) Ventral view of the disk. Scale bar: 2 mm. (k) Disk ornament spinelets. Scale bar: 0.15 mm. (l) Ventral arm view. \*: Ventral arm plate. Arrowhead: Tentacle scales. Scale bar 0.25 mm. (m) Dorsal arm plates. Scale bar: 0.5 mm. (n) Arm spines. Scale bar: 0.25 mm. (o) Jaw. Scale bar: 0.25 mm. *Ophiosabine notata*: (ID: 1574974) (p) Dorsal view of the disk. Scale bar: 1.5 mm. (q) Ventral view of the disk. Scale bar: 1.5 mm. (r) Dorsal arm plates. Scale bar: 0.12 mm. (s) Arm spines. Scale bar 0.5 mm. (t) Ventral arm view. \*: Ventral arm plate. Arrowhead: Tentacle scales. Scale bar: 0.12 mm. (u<sub>1</sub>) Disk ornament spinelets. Scale bar: 0.1 mm. (u<sub>2</sub>) Cenital view of the disk spinelets. Scale bar: 0.1 mm. (v) Jaw. Scale bar: 0.5 mm. *Ophiosabine parvita*: (ID: 1574975) (w) Dorsal view of the disk. Scale bar: 1 mm. (x) Ventral view of the disk. Scale bar: 1 mm. (y) Ventral arm view. \*: Ventral arm plate. Arrowhead: Tentacle scales. Scale bar: 0.25 mm. (z) Arm spines. Scale bar: 0.5 mm. (z<sub>1</sub>) Dorsal arm plates. Scale bar: 0.25 mm. (z<sub>2</sub>) Disk ornament spinelets. Scale bar: 0.1 mm. (z<sub>3</sub>) Jaw. Scale bar: 0.2 mm. (I) Species distribution map.

### Family Ophiobryidae

#### *Ophiobryx spinosus* (Storm, 1881)

AphiaID: 125146

Material examined: 1 preserved specimen from station A410DR8.

Diagnostic characters: Rounded, raised disk covered by thick skin (Figure 9a,b), with small spines scattered on plates (Figure 9a). Short radial shields bar-shaped and covered by a row of well-developed spines along their entire length (Figure 9c). Jaws covered by skin, up to 3 apical papillae, flanked by 3 lower oral papillae. The second pore emerges in the mouth without associated scales. Rhombic/rounded oral shield (Figure 9d). Arms covered by skin, 2 oval dorsal arm plates (Figure 9e), pentagonal/rounded ventral arm plates. Very large tentacle pores without scales (Figure 9f). Five rough arm spines covered by skin (Figure 9g).

Distribution: North Atlantic Ocean, British Isles, Faroe Islands, Iceland, off the coast of Morocco (Figure 9I).

Bathymetric range: 377 m [50]–1405 [48]. Present study: 844 m.

Remarks: *Ophiobryx spinosus* species is easily distinguished from the rest by its thick skin with scattered plates and spines covering the disk (Figure 9a,b), the radial shields with a row of spines (Figure 9c) and its characteristic dorsal arm plates, divided longitudinally by a groove along the entire arm into 2 small oval plates (Figure 9e). For example, in the case of the species *Ophiobryx quadrispinosus* (Koehler, 1914), also present in the North Atlantic, there are no spines on the disk or on the radial shields, and it does not have dorsal arm plates, only a slightly calcified integument.

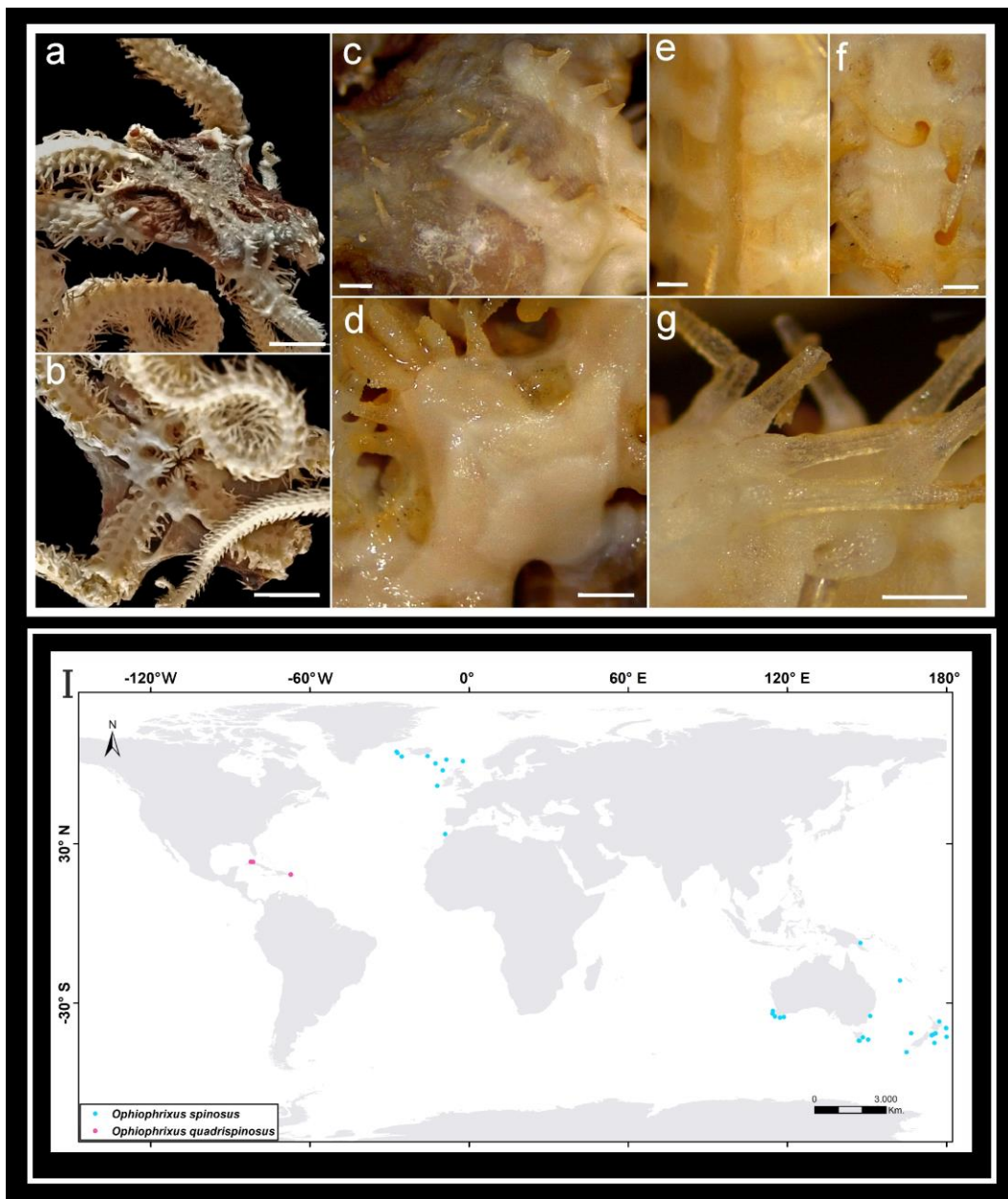
### Family Ophiotomidae

#### *Ophiotreta valenciennesi* (Lyman, 1879)

AphiaID: 244220

Material examined: 1 preserved specimen from station A11DR7.

Diagnostic characters: Round disk, wholly covered by rugose low granules dorsally (Figure 10a) and in the ventral interradial areas (Figure 10b). Only radial shield tips visible. One or 2 apical papillae flanked each side by up to 6 pointed to scale-like papillae. Slightly wing-shaped adoral shields. Large and rounded arrow-shaped oral shield (Figure 10c). Contiguous and bell-shaped dorsal arm plates (sometimes with a distal lobe with small spines on the edge) (Figure 10d). Almost pentagonal ventral arm plates wider than long. Large tentacle pores armed with 2 scale-like and flat tentacle scales (1st tentacle pores sometimes with 3 tentacle scales) (Figure 10e). Seven to eight flattened, finely rugose and square-tipped arm spines, not forming a fan in proximal segments (Figure 10f).



**Figure 9.** *Ophiophrixus spinosus*: (ID: 125146) (a) Dorsal view of the disk. Scale bar: 5 mm. (b) Ventral view of the disk. Scale bar: 5 mm. (c) Radial shields. Scale bar: 0.5 mm. (d) Jaw. Scale bar: 1 mm. (e) Dorsal view of the arm. Scale bar: 0.25 mm. (f) Ventral view of the arm. Scale bar: 0.3 mm. (g) Arm spines. Scale bar 0.3 mm. (I) Species distribution map.

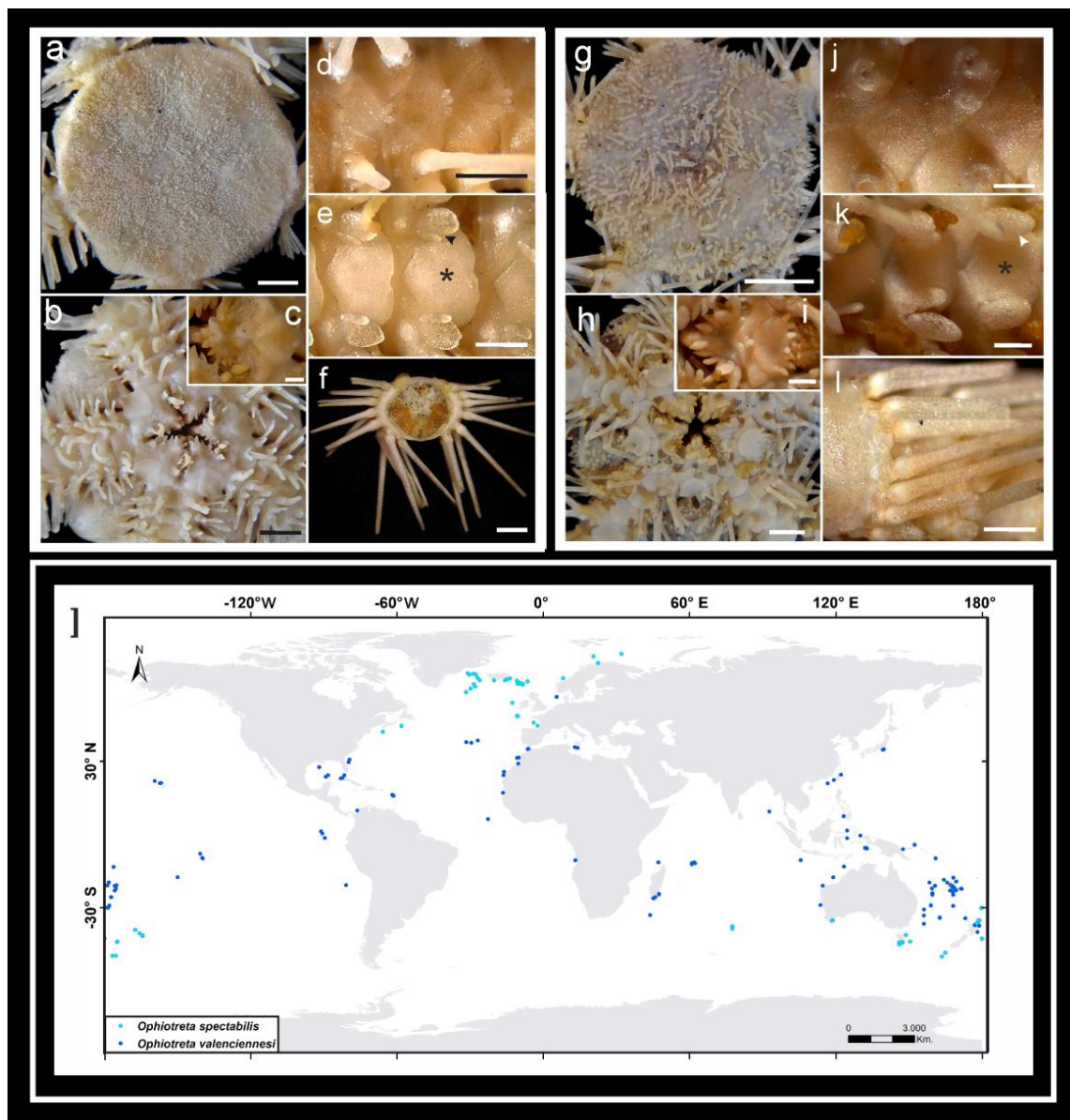
Distribution: Gulf of Mexico, Caribbean Sea, northwest Africa, New Caledonia, Japan, Taiwan, Philippines, Indonesia, New Zealand, Galapagos Islands, Hawaii, Mediterranean Sea [52] (Figure 10I).

Bathymetric range: 22 m [48]–1901 m [53]. Present study: 551 m.

Remarks: *Ophiotreta valenciennesi* can be distinguished from the other species of *Ophiotreta* present in the Bay of Biscay, *Ophiotreta spectabilis* (G.O. Sars, 1872) (Figure 10g–l), by the ornamentation of the disk, being low granules in *O. valenciennesi* (Figure 10a) and elongated and rough rods with a narrow 3-pointed crown (Figure 10g). They also differ in the dorsal arm plates, separated in *O. spectabilis* (Figure 10j) and contiguous (sometimes with granules at the distal end) in *O. valenciennesi* (Figure 8d). In *O. spectabilis* the oral shield



is rounded pentagonal/oval with short spinelets or granules on the distal edge (Figure 10i), while in *O. valenciennesi* it is arrow-shaped (sometimes rounded) (Figure 10c).



**Figure 10.** *Ophiotreta valenciennesi*: (ID: 244220) (a) Dorsal view of the disk. Scale bar: 2 mm. (b) Ventral view of the disk. Scale bar: 1.5 mm. (c) Jaw. Scale bar: 0.3 mm. (d) Dorsal arm plates. Scale bar: 1 mm. (e) Ventral arm view. \*: Ventral arm plate. Arrowhead: Tentacle scales. Scale bar: 0.5 mm. (f) Arm spines. Scale bar 1 mm. *Ophiotreta spectabilis*: (ID: 1589839) (g) Dorsal view of the disk. Scale bar: 2 mm. (h) Ventral view of the disk. Scale bar: 1 mm. (i) Jaw. Scale bar: 0.4 mm. (j) Dorsal arm plates. Scale bar: 0.25 mm. (k) Ventral arm view. \*: Ventral arm plate. Arrowhead: Tentacle scales. Scale bar: 0.4 mm. (l) Arm spines. Scale bar 0.25 mm. (I) Species distribution map.

#### 4. Discussion

Despite the scarcity of studies on ophiuroids from Spanish waters, some ophiuroid checklists are available. The most important one is that of the IEEM (Ophiuroidea [42,43]). This checklist was compiled based on the creation of a series of geographic polygons that delimited the Spanish waters, and among them NAMD was defined, where the ACS is located (Figure 1b). This checklist is considered as a great effort toward making a complete list which includes all records of species collected in the area from different surveys (own data

or campaign reports) and records from bibliographic references, among other resources. Many of these records are not ratified by specialists, which makes it more difficult to analyze their reliability. However, this is the first attempt at building a showcase for Spanish marine diversity studies, and therefore it should be extensively revised and improved. In the near future, thirteen species should be added to the IEEM as result of the records from the bibliography and a deep dataset review at the study area: *Amphiophiura bullata*, *Stegophiura macrarthra*, *Ophiocten centobi*, *Amphiura borealis*, *Amphiura fragilis*, *Ophiacantha crassidens*, *Ophiochondrus armatus*, *Ophiolimna bairdi*, *Ophiosabine cuspidata*, *Ophiosabine parcita*, *Ophiophrixus spinosus*, *Ophiotreta valenciennesi* and *Ophiolycus purpureus*. Moreover, seven more species could be included as new records for the NAMD (based on the present study): *Ophiocten centobi*, *Amphiura borealis*, *Amphiura fragilis*, *Ophiosabine parcita*, *Ophiochondrus armatus*, *Ophiophrixus spinosus* and *Ophiotreta valenciennesi*. Although these last three were already cited in a previous publication [33], the morphological and bathymetric details were not included, nor was a comparison of the taxonomic characteristics with those of very similar species conducted to rule out a misidentification.

Although there are some species of the genus *Ophiocten* present all around the area (Figure 2), such as *O. hastatum*, *O. affinis* and *O. sericeum*, *O. centobi* had not been collected within the Bay of Biscay; it was recorded just within the limit in deep bottoms (Figure 3I). This species typically lives in deeper bottoms than those sampled before in the area, and the study of the canyons enabled us to find it.

Ten species of the genus *Amphiura* have been recorded in NAMD (see Figures 4–6); among them, only two lack tentacle scales (like the new records *A. borealis* and *A. fragilis* (Figure 4)): *A. abyssorum* and *A. filiformis*. These four species could be identified by paying attention to the arm spine shape (see remarks above), although all the specimens identified as *A. borealis* have 6 arm spines (Figure 4f). We do not think this difference from the original description is enough to describe a new species; however, we try to describe this variability present in the four specimens from ACS as well as in 4 specimens sampled by other surveys and projects in nearby areas, which will be included in future papers. On the other hand, the *O. borealis* distribution area is almost Arctic-circumpolar, which makes us think our specimens could be assigned to *O. filiformis* (with a wider distribution area) (Figure 6II), taking into account the variability in the number of arm spines (5–7), but all specimens meet the *O. borealis* description, and they only have one axe-shaped arm spine per segment.

The closest records of *Ophiochondrus armatus* to the study area are in British waters (Mortensen, 1927) and the mid-Atlantic [22], but Mortensen [38] already noted that these records could not be the same species. The problem lies mainly with respect to two characteristics: divided dorsal arm plates and disk ornament. Divided dorsal arm plates are a character shared with *Ophiolebes resecta*, a species also distributed in our study area, and this may lead to misidentifications. Our specimens were identified on the basis of disk spines—in *O. resecta*, these ornaments are described as granules—and divided and contiguous dorsal arm plates (Figure 7).

The most common species of the genus *Ophiosabine* in our area is *O. aristata*, followed by *O. notata*. The distribution range of *O. parcita* is outside of the Bay of Biscay and quite restricted. It has only two records: one in the north of British waters and another in the mid South Atlantic Ocean. Although *O. notata* and *O. parcita* have striations on the ventral and lateral plates of the arm, these three species are easy to separate based on two constant characteristics: the shape of the disk spinelets (Figure 8u<sub>1</sub>,u<sub>2</sub>) and the shape of the oral shield (Figure 8v,z<sub>3</sub>). Despite the differences in morphology that could be identified, the number of specimens recorded (10 specimens, and more in other projects on the Galicia Bank: 4 specimens) and the adjustment of its morphology to the original description [15], maybe *O. parcita* has been confused with *O. aristata*, which is the most frequent species in the area.

*Ophiophrixus* is a genus which only contains four species, *O. acanthinus* H.L. Clark, 1911, and *O. confinis* Koehler, 1922 (Pacific Ocean distribution), and two Atlantic species (Figure 9), *O. quadrispinosus* and *O. spinosus*. Although these last species present similar morphologies,

our specimen has spines on the disk and on the radial shields and conspicuous dorsal plates, so it was identified as *O. spinosus*. Nevertheless, *O. spinosus* is not a very frequent species; it has mostly been found in North Atlantic/circumpolar Arctic waters, although there is a record off Morocco. This is the first record from the Bay of Biscay.

Finally, *Ophiotreta spectabilis* seems to prefer colder waters than *O. valenciennesi* (see distribution map in Figure 10); however, O'Hara et al. [54] have described the presence of *O. spectabilis* in *Solenosmilia* Duncan, 1873 corals, and so it is typically found deeper than *O. valenciennesi*, at least in the distribution area (from the North Atlantic all the way to Australia) following Victorero et al. [48]. In any case, a detailed study of the dorsal plates and oral shield among other characters lead us to identify this specimen as *O. valenciennesi*, and report it as a new record.

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**Data Availability Statement:** The data presented in this study are available on request from the corresponding author due to privacy.

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