BIODIVERSITY AND DISTRIBUTION OF POLYMASTIIDAE (DEMOSPONGIAE, HADROMERIDA) IN THE ARCTIC AREA

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ABSTRACT

Sponges of the family Polymastiidae inhabiting the Arctic region were revised and compared with the North Atlantic fauna. Twelve polymastiid species from 6 genera are recognised in the studied area, 10 of them are considered to be widely spread in both Arctic and Atlantic. The range of the 2 species is restricted only to the Arctic.

KEY WORDS

Polymastiidae, Arctic, biodiversity, distribution.

INTRODUCTION

Sponges of the family Polymastiidae are characterised by a well-defined cortex with the external layer being always a palisade of specific spicules, a radiating choanosomal skeleton and a simple shape of all spicules which are always monaxonic (BOURY-ESNAULT, 2002). Recent authors studying the taxonomy of these sponges pay most attention to the skeleton arrangement and structure of the cortex, choanosome and papillae. Using these characters BOURY-ESNAULT (2002) has revised the genera belonging to the family. Polymastiidae are spread world-wide but especially common in temperate and polar waters. Two areas are particularly well-known, NE Atlantic and Mediterranean (BOURY-ESNAULT, 1987; BOURY-ESNAULT *et al.,* 1994) and SW Pacific (KELLY-BORGES & BERGQUIST, 1997). Seventeen nominal species from 10 nominal genera of Polymastiidae have been reported in the Arctic area (SCHMIDT, 1870; MEREJKOWSKY, 1878; VOSMAER, 1885; SWARCZEWSKY, 1906; TOPSENT, 1913; REZVOJ, 1927; KOLTUN, 1964, 1966; ERESKOVSKY, 1993). These numerous outdated descriptions evidently need revision. The aim of this work is to provide such a revision and to compare the Arctic Polymastiidae with the North Atlantic species.

MATERIAL AND METHODS

Type specimens of *Polymastia arctica* (Merejkowsky, 1878), *Polymastia euplectella* Rezvoj, 1927, *Polymastia thielei* Koltun, 1964 and *Sphaerotylus borealis* (Swarczewsky, 1906) have been studied in the Zoological Institute of Russian Academy of Sciences (ZIRAS). Type specimen of *Polymastia mamillaris* (Müller, 1806) has been examined in the Zoological Museum of Copenhagen University (ZMUC). Type material of *Polymastia penicillus* (Montagu, 1818),

Polymastia robusta (Bowerbank, 1861), *Polymastia grimaldi* (Topsent, 1913), *Sphaerotylus capitatus* (Vosmaer, 1885), *Radiella sarsi* (Ridley & Dendy, 1886), *Quasillina brevis* (Bowerbank, 1862) and *Quasillina richardi* Topsent, 1913 has been studied only at fragments and slides stored in the Station Marine d'Endoume (SME). All other sponge samples of ZIRAS, ZMUC, SME and the Shirshov Institute of Oceanology of Russian Academy of Sciences (IORAS) have been also studied. Type specimens of other five species recorded in the Arctic area, namely *Polymastia uberrima* (Schmidt, 1870), *Radiella hemisphaericum* (Sars, 1872), *Weberella bursa* (Müller, 1806) and *Tentorium semisuberites* (Schmidt, 1870) seem to have disappeared. These species have been revised using only non-type material.

Skeleton arrangement was observed in thick sections of body and papillae. For this purpose sponge fragments fixed in ethanol were dehydrated, embedded in the araldite and cut by a diamond saw. Resulted sections were mounted on slides, polished and stained by toluidine blue. For observations of spicule shape and size sponge fragments were digested in nitric acid directly on the slides.

RESULTS

Tab. I. Spicule dimensions of Arctic Polymastiidae: length is given in the upper row; diameter is given in the lover row; means are given in brackets. Numbers refer to: **1,** *P. arctica*. **2,** *P. euplectella*. **3,** *P. thielei*. **4,** *P. uberrim*. **5,** *P. grimaldi*. **6,** R. *hemisphaericum*. **7,** R. *sarsi*. **8,** *S. capitatus*. **9,** *S. borealis*. **10,** T. *semisuberites*. **11,** *W. bursa*. **12,** *Q. brevis*. Ten specimens of each species, except *P. arctica* (40 observed specimens) were observed. Ten spicules of each category were measured for each specimen.

Species	Dimensions of spicules, μm			
	Principal	**Intermediary**	**Ectosomal**	**Additional**
1	620-(868)-1100 8.8-(14.3)-20	270-(414)-550 5-(9.5)-17.5	120-(161)-215 3.8-(4.8)-6.3	Absent
2	1135-(1472)-1800 18.4-(23.7)-30	527-(671)-773 8.9-(11.3)-17.5	95-(172)-260 3-(4.2)-6.5	Absent
3	700-(1290)-1700 12.9-(18.5)-25.1	450-(538)-650 10.7-(11.1)-12.2	220-(302)-360 4.5-(6.5)-9.1	Absent
4	715-(1199)-1670 10.7-(17.5)-24.8	450-(574)-654 8.2-(11.9)-14.4	263-(298)-327 3.3-(4.8)-6.7	Absent
5	1450-(2365)-3240 21.2-(24.7)-29	210-(446)-670 20.9-(22)-24	147-(236)-286 3.9-(6.1)-7.6	2020-(4535)-7000 8-(9.3)-10.5
6	2280-(3810)-5400 11.2-(21.5)-32.3	490-(571)-618 19.2-(22.3)-26.2	160-(232)-305 4.2-(5.9)-8.4	4990-(6506)-8010 45.8-(48.1)-50.1
7	871-(1787)-2900 13-(19.3)-26.6	152-(229)-290 8.1-(9.7)-10.3	250-(448)-600 6.1-(7.5)-8.5	5090-(5537)-6030 27.4-(28.5)-29.8
8	650-(998)-1505 14.5-(19.7)-24	314-(457)-605 10.3-(13.8)-16.1	96-(166)-221 2.3-(4.9)-6.4	650-(940)-1250 18-(18.7)-19.8
9	1100-(1535)-2100 12.1-(14.2)-19.2	200-(507)-796 6.6-(10.3)-14.4	94-(131)-160 2.7-(3)-4.1	5100-(6343)-7520 5.1-(11.8)-20
10	810-(1589)-2400 13.4-(22)-30	Absent	274-(468)-670 12.8-(16.2)-19.3	Absent
11	420-(541)-700 10.8-(11.4)-12.6	Absent	90-(199)-270 1.9-(3.5)-5.1	Absent
12	570-(807)-1040 11.2-(17.5)-25.1	Absent	140-(214)-300 1.9-(3.9)-5.7	Absent

Brief diagnoses for the studied species are reported. Their external morphology, skeleton structure and geographical data are showed in the Figs 1-3 respectively. Dimensions of their spicules are given in Tab. I.

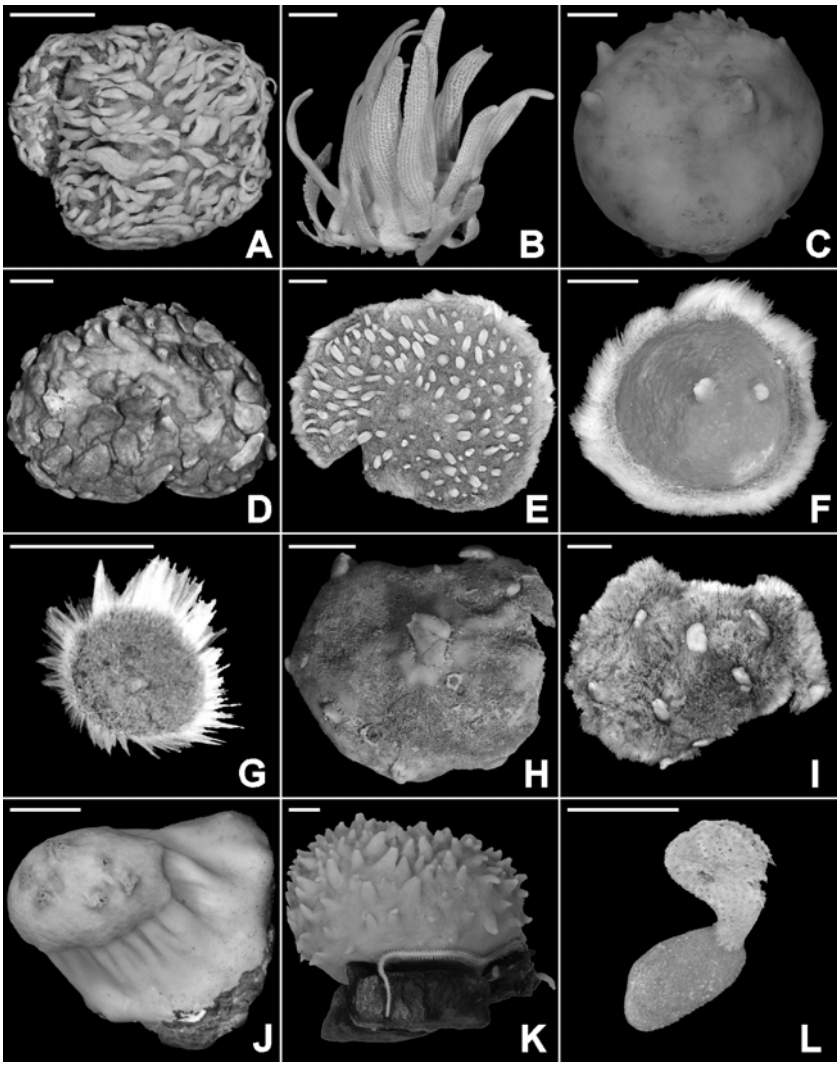

Fig. 1. Arctic Polymastiidae: External morphology. **A,** *P. arctica,* lectotype, ZIRAS N 84a (5526), White Sea. **B,** *P. euplectella,* holotype, ZIRAS N 7 (50004), Barents Sea. **C,** *P. thielei,* syntype, ZIRAS N 7 (50005), Greenland Sea. **D,** *P. uberrima,* ZIRAS N 57 (13362), Barents Sea. **E,** *P. grimaldi,* personal collection of the author, White sea. **F,** *R. hemisphaericum,* ZIRAS N 45 (4953), Barents Sea. **G,** *R. sarsi,* ZIRAS N 3 (6139), Greenland Sea. **H,** *S. capitatus,* ZIRAS N 6 (50001), Barents Sea. **I,** *S. borealis,* personal collection of the author, White Sea. **J,** T. *semisuberites,* ZIRAS N 157 (50002), Barents Sea. **K,** *W. bursa,* ZIRAS N 37 (50003), Barents Sea. **L,** *Q. brevis,* ZIRAS N 4 (5577), Kara Sea. Scale bars: 1 cm.

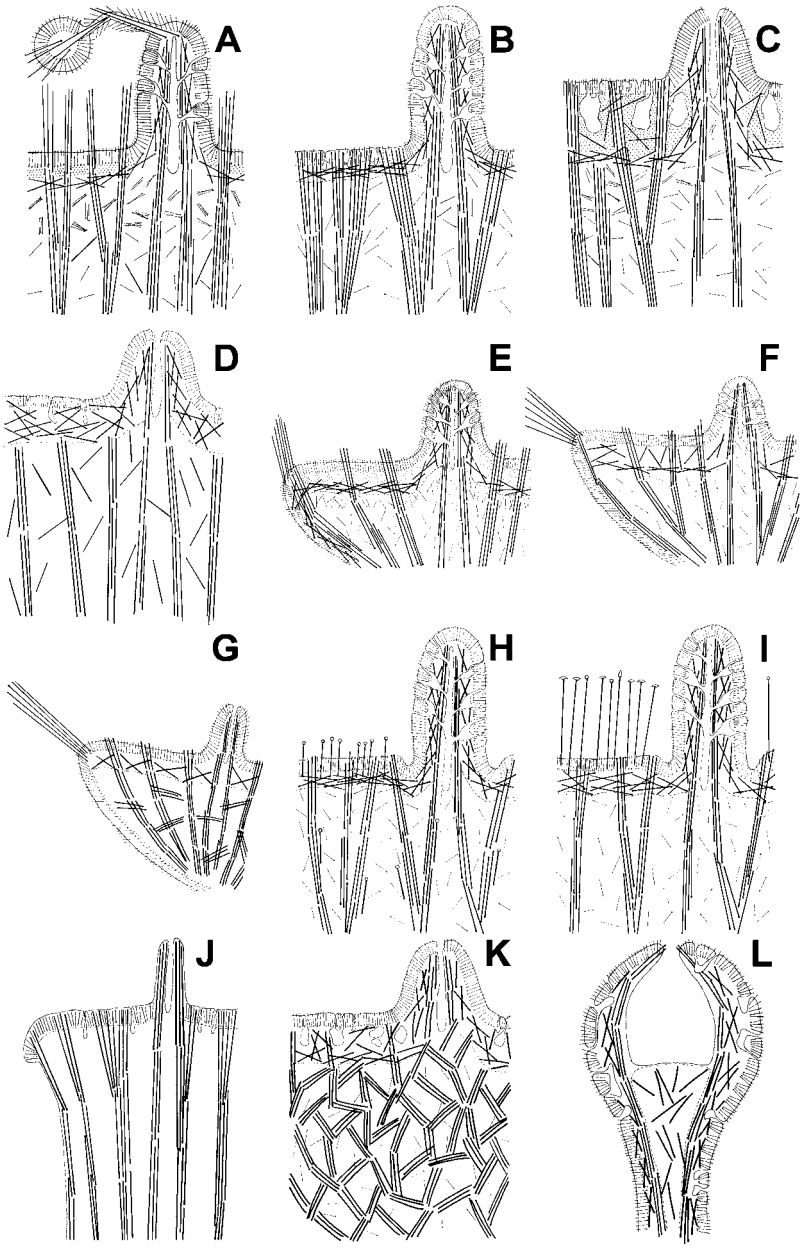

Fig. 2. Arctic Polymastiidae: Structure of skeleton. **A,** *P. arctica*. **B,** *P. euplectella*. **C,** *P. thielei*. **D,** *P. uberrima*. **E,** *P. grimaldi*. **F,** *R. hemisphaericum*. **G,** *R. sarsi*. **H,** *S. capitatus*. **I,** *S. borealis*. **J,** *T. semisuberites*. **K,** *W. bursa*. **L,** *Q. brevis*.

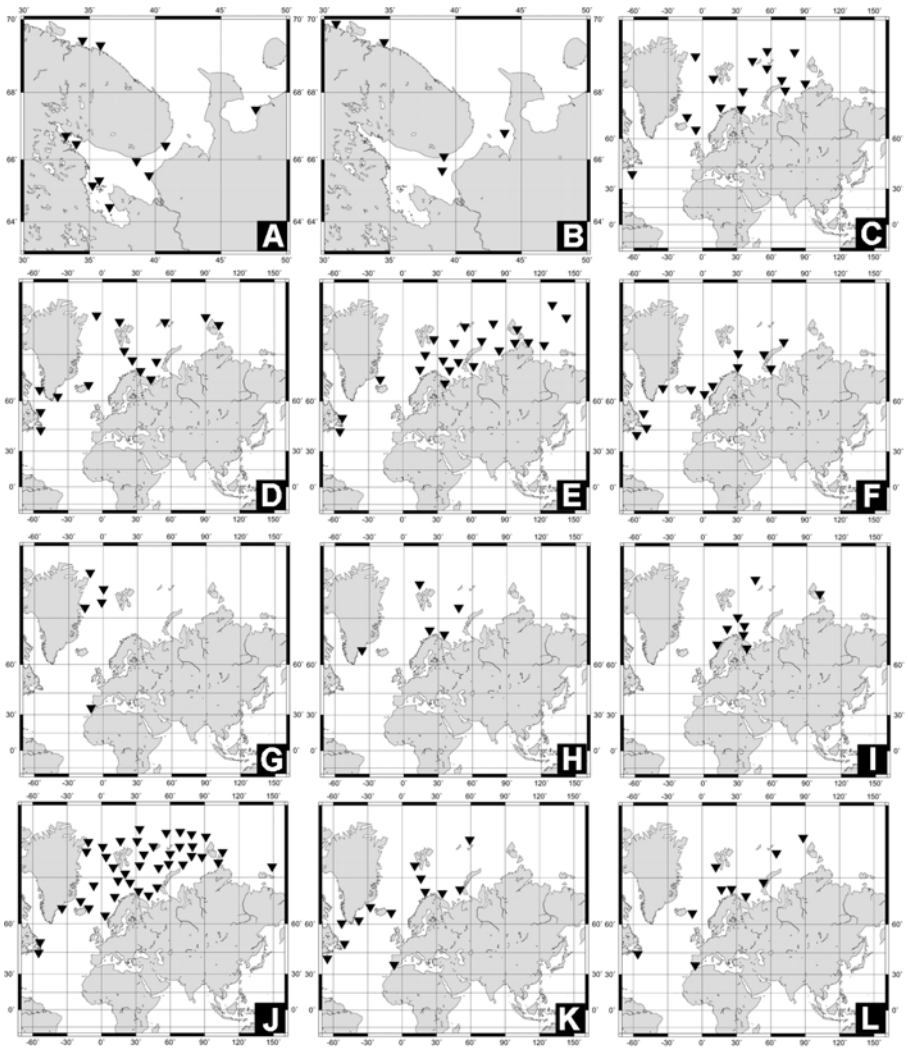

Fig. 3. Arctic Polymastiidae: Distribution. **A,** *P. arctica*. **B,** *P. euplectella*. **C,** *P. thielei*. **D,** *P. uberrima*. **E,** *P. grimaldi*. **F,** *R. hemisphaericum*. **G,** *R. sarsi*. **H,** *S. capitatus*. **I,** *S. borealis*. **J,** T. *semisuberites*. **K,** *W. bursa*. **L,** *Q. brevis*.

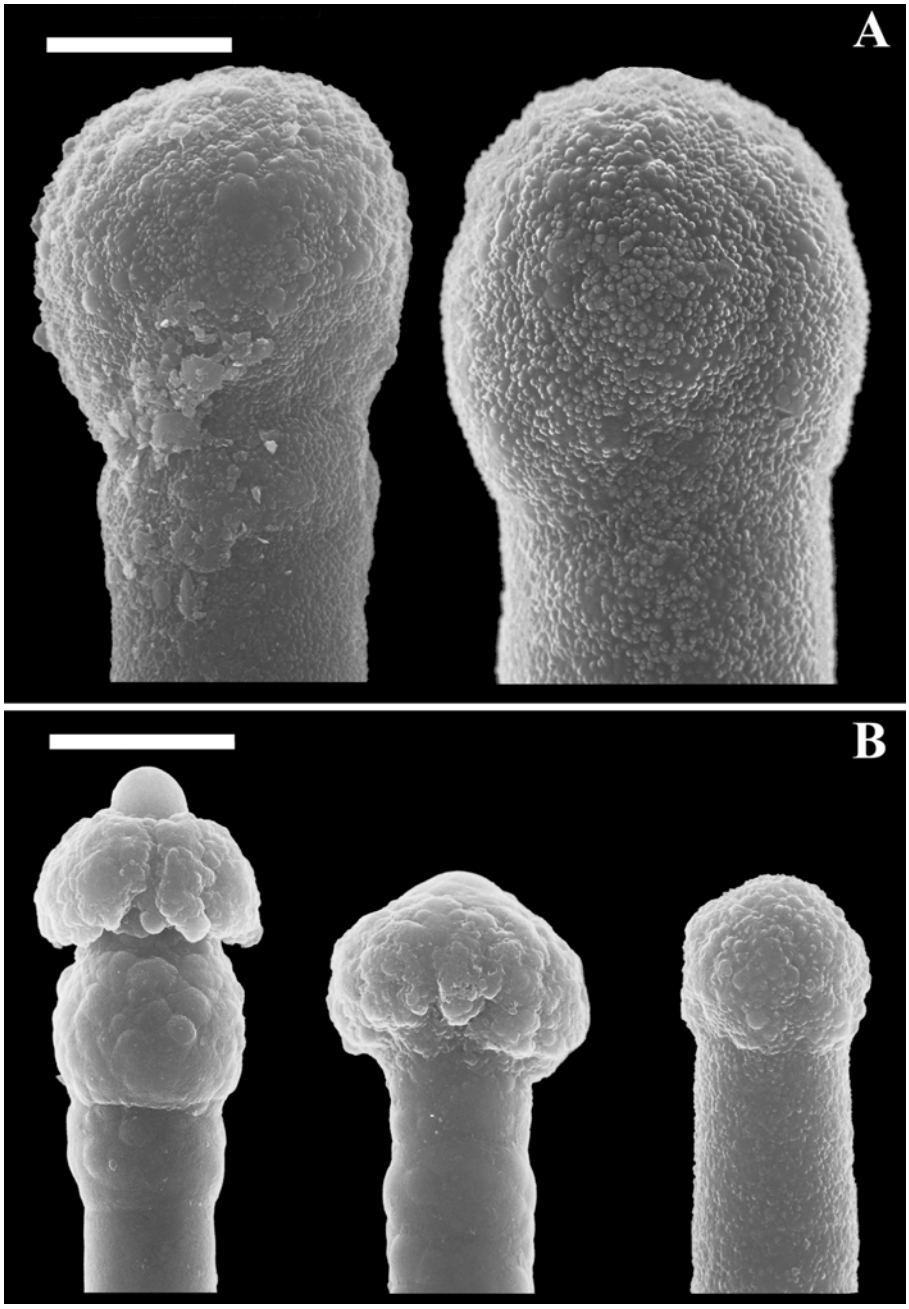

Fig. 4. Arctic *Sphaerotylus*: distal heads of exotyles. **A,** *S. capitatus*, ZIRAS N 9 (14714), Greenland Sea. **B,** *S. borealis,* holotype, ZIRAS N 34 (9138), White Sea. Scale bars: 13.6 μm.

Polymastiidae Gray, 1867

Polymastia Bowerbank, 1864

Thickly encrusting sponges always with papillae. The choanosomal skeleton is composed of radial tracts of principal spicules between which free spicules are scattered. The cortical skeleton is composed of at least two layers - an external palisade of small tylostyles and an inner tangential layer of intermediary spicules.

Polymastia arctica (Merejkowsky, 1878)

Thickly encrusting cushion-shaped sponges with hispid surface. Adults can bear more than 100 inhalant papillae and 1 - 15 exhalant ones. Buds often develop on threads growing from top of papillae. The choanosomal skeleton includes radial tracts of principal subtylostyles and groups of small tylostyles scattered between them. The latter are especially abundant below the cortex (subcortical layer). The cortex is constituted by an external layer of palisade arranged small tylostyles, a middle collagenous layer and an internal tangential layer made of intermediary subtylostyles. Principal spicule tracts pass through the cortex causing hispidation. Several spicule tracts, ascending from the choanosome, form the axial framework of the papillae. Some of them may fuse at the summit forming an extension, which is the central axis of a bud thread. The thread is echinated by small tylostyles. The bud skeleton consists of a superficial tylostyle palisade, free scattered intermediary spicules inside and some principal spicules of the thread, which cross the bud. The papilla wall consists of the palisade and tangential layers. The exhalant papilla possesses a central exhalant canal and several peripheral inhalant ones. The inhalant papilla has only one canal.

Polymastia euplectella Rezvoj, 1927

Cushion-shaped sponges with very long papillae. Their number does not exceed 30 per specimen. The body surface is smooth or slightly hispid. Radial choanosomal tracts are made of principal styles. Small tylostyles are scattered between the tracts. They also constitute the external cortical palisade under which a tangential layer of intermediary subtylostyles is located. Ostioles and small vestibules are observed between the tylostyles. Principal spicule tracts cross the cortex but usually do not cause a surface hispidation. The major central area of the papillae is occupied by a single canal (inhalant or exhalant). From the inside to the outside the papilla wall consists of the ascending tracts, the tangential layer and the palisade one. The tracts are criss-crossed by the intermediary spicules.

Polymastia thielei Koltun, 1964

Massive spherical or fist-shaped sponges. The surface is smooth or slightly hispid. Crater-like exhalant papillae are located at the upper surface. Their number does not exceed 30. Radial tracts of principal subtylostyles and free scattered small tylostyles form the choanosomal skeleton. The latter spicules are especially abundant in the subcortical area. The cortex includes an irregular palisade of small tylostyles, a middle layer of large vestibules connected with ostioles at the surface and an internal tangential layer of intermediary tylostyles. Principal spicule tracts cross the cortex

without causing hispidation. The papilla axial framework is formed by the ascending tracts. The papilla wall is constituted by the tangential layer and the palisade. The single exhalant canal is located at the centre of each papilla.

Polymastia uberrima (Schmidt, 1870)

Massive spherical or cushion-shaped sponges with thick and short exhalant papillae. The number of papillae may be up to 100 per specimen. The body surface is smooth. The choanosomal skeleton includes radial tracts of principal strongyloxea and free scattered intermediary tylostyles. A palisade of small tylostyles and a paratangential irregular layer of intermediary spicules constitute the cortex. There are also small vestibules in the cortex but they do not constitute a separate layer. Choanosomal spicule tracts may cross the tangential layer. The papilla wall has the same structure as the cortex. Principal spicule tracts form the axial framework. The single exhalant canal in each papilla is surrounded by several inhalant ones.

Polymastia grimaldi (Topsent, 1913)

Discoid or hemispherical sponges attached to substrata only by the central point. The upper surface is hispid and the basal one, lying on the soft sediment, is smooth. A spicule fringe is observed at the border between the upper and basal surfaces. Leaf-like inhalant papillae are numerous (usually more than 100 in adults) and there is usually a single conical exhalant papilla in the centre of the upper surface. The radial tracts of the choanosomal skeleton, constituted by principal strongyloxea, start from the attaching point of the base, underlying the basal cortex, pass through the upper one and cause the hispidation. Small tylostyles are scattered between the tracts especially concentrating below the cortex. The cortex consists of a small tylostyle palisade, a middle collagenous layer and a tangential layer of intermediary tylostyles. Extremely long and thin styles arise from the edge areas of the upper cortex and constitute the fringe. The papilla wall resembles the upper cortex though it lacks the collagenous layer. An axial framework of spicule tracts is present. Every papilla possesses a single central canal, being exhalant or inhalant.

Radiella Schmidt, 1870

Discoid or hemispherical sponges always with papillae. The choanosomal skeleton is constituted by principal spicule tracts emanating from a central nucleus at the sponge base and by free-scattered spicules. The upper cortex may consist of one or two layers. The lower surface is enveloped by the principal tracts and contains a single palisade layer of tylostyles. A fringe of additional spicules is observed at the border between the upper and the lower surface.

Radiella hemisphaericum (Sars, 1872)

Hemispherical sponges attached to substrata by a central point. The upper surface is smooth and the basal one is slightly hispid. A spicule fringe is well-developed at the junction of the surfaces. Few small papillae (not more than 20 per specimen) are scattered in the central area of the upper surface. The radial tracts of principal subtylostyles emanate from the central nucleus of the sponge base, envelope the basal part of the body and cross the upper surface without causing

hispidation. Few tracts may pass through the basal enveloping and cortex and echinate it. Small tylostyles are scattered in the choanosome between the tracts. The upper cortex consists of the tylostyle palisade and an irregular paratangential layer of intermediary spicules. The basal cortex includes the single external palisade layer. The edge fringe is constituted by the long styles. The papilla wall resembles the upper cortex. The axial framework of the ascending tracts is also observed in the papillae. Every papilla possesses a central canal, being exhalant or inhalant.

Radiella sarsi (Ridley & Dendy, 1886)

Discoid, lenticular or hemispherical small sponges attached to substrata by a central point or lying on the soft sediment. The upper surface is slightly hispid and the basal one is smooth. The size of the edge fringe may exceed the body radius. The single exhalant papilla is centrally located. The structure of the choanosomal and cortical skeleton resembles the one of *R. hemisphaericum*. However in *R. sarsi* free spicules of the choanosome are intermediary subtylostyles arranged in small groups. As to the radial tracts they may echinate the upper surface. The papilla skeleton is alike that of other *Radiella,* though in *R. sarsi* the central exhalant canal is surrounded by several inhalant apertures.

Sphaerotylus Topsent, 1898

Thickly encrusting sponges always with papillae. The choanosomal skeleton is composed of radial tracts of principal spicules and free-scattered spicules. The cortical skeleton consists of an external tylostyle palisade and a tangential layer. Exotyles with spherical or paraspherical distal heads reinforce the surface (Fig. 4).

Sphaerotylus capitatus (Vosmaer, 1885)

Thickly encrusting cushion-shaped sponges. The surface is slightly hispid. The papillae are small and their number does not exceed 20 per specimen. The choanosomal skeleton is constituted by the radial tracts of principal tylostyles and free-scattered small tylostyles. The cortex consists of a tylostyle palisade and a tangential layer of intermediary subtylostyles. The principal tracts cross the cortex without causing hispidation. The latter is constituted by the exotyles with spherical distal heads – spherotylostyles (Fig. 4a). These spicules were also observed in the choanosome of some specimens. The papilla skeleton includes the axial framework of tracts and the cortex-like wall. Some specimens lack the inner tangential layer and all sponges lack exotyles in the papilla wall. The canal structure of the papillae remains unclear.

Sphaerotylus borealis (Swarczewsky, 1906)

Thickly encrusting cushion-shaped sponges. The surface is extremely hispid. The papillae are small and their number does not exceed 30 per specimen. The choanosomal skeleton is constituted by the radial tracts of principal styles and free-scattered small tylostyles. The cortex is constituted by a tylostyle palisade and a parapalysade irregular layer of intermediary subtylostyles. Both are echinated by the tracts ascending from the choanosome and by very long exotyles. The heads of the latter display a great variety in shape, being spherical, hemispherical, cone-like or

even smooth (Fig. 4b). No exotyles were observed in the choanosome. The papilla skeleton consists of the spicule axial framework of tracts and the cortex-like wall without exotyles. Each papilla possesses a central exhalant canal and several inhalant ones at the periphery.

Tentorium Vosmaer, 1887

Columnar or globular sponges always with papillae. The choanosomal skeleton is constituted by the principal spicule tracts. Some of the tracts envelope the body in a sheath. The cortex, restricted to the upper surface, is composed by a single palisade layer.

Tentorium semisuberites (Schmidt, 1870)

Column-shaped sponges whose lateral surface is always smooth and the upper one may be slightly echinated. Few small papillae (1 - 20 per specimen) are concentrated in the centre of the upper surface. Tracts of principal subtylostyles constitute a cylindrical sheath enveloping the body. They also constitute the choanosomal skeleton. No free spicules are observed in the choanosome. The cortex, restricted to the upper surface and crossed by the tracts, consists of a single palisade of small tylostyles. Vestibules are located in the cortex. The papillae wall is formed only by the ascending tracts surrounding the central exhalant canal.

Weberella Vosmaer, 1885

Sponges always with papillae. The choanosomal skeleton is reticulate. The cortical skeleton consists of a palisade and a paratangential layer. Only two spicule categories are observed.

Weberella bursa (Müller, 1806)

Fist-like, globular or cushion shaped sponges with smooth surface. The exhalant papillae are numerous (50 - 100 per specimen) and very small. The choanosomal skeleton is constituted by a mesh of principal subtylostyle tracts and small tylostyles scattered between them. The cortex consists of a tylostyle palisade and an irregular parantangential layer of subtylostyles which are analogous to the principal ones. Large vestibules are observed in the cortex. The choanosomal tracts cross the cortex and also constitute the papillae axial skeleton. The papilla wall has the same structure as the cortex though it lacks vestibules. The single exhalant canal is located in the centre.

Quasillina Norman, 1869

Stalked sponges with an ovoid body, without papillae. The choanosomal skeleton is restricted to free-scattered spicules. The cortical skeleton consists of ascending tracts of principal spicules, an internal tangential layer and an external palisade. Two or three size categories of spicules are observed.

Quasillina brevis (Bowerbank, 1862)

Pedunculated sponges with ovoid body. The surface is usually smooth. No papillae are observed. The single osculum is located at the body summit. The choanosome is reduced and its skeleton is constituted only by scattered spicules. Tracts of subtylostyles lying parallel to the surface pass through the cortical inner tangential layer consisting of the same spicules. These tracts may slightly echinate the oscule opening. The outer layer of the cortex is a palisade of small subtylostyles or styles. Vestibules are observed within the cortex.

DISCUSSION AND CONCLUSIONS

Twelve valid species and 6 genera of Polymastiidae have been recognised for the Arctic area. Five species belong to the genus *Polymastia*. The validity of 3 species - *P. arctica*, *P. euplectella* and *P. thielei* - is reestablished. The taxonomic position and composition of 2 other ones - *P. uberrima* and *P. grimaldi* - still remain questionable.

P. arctica was previously included in "*P. mamillaris*" complex (VOSMAER, 1885; KOLTUN, 1966; ERESKOVSKY, 1993) that was considered by Koltun widely spread in the North Hemisphere. The confusion between *P. mamillaris* (known only from the Swedish West coast) and *P. penicillus* (widely spread in the North Atlantic) was recently stopped by MORROW & BOURY-ESNAULT (2000). *P. arctica* differs from these two relative species by budding and by the presence of a thick collagenous layer in the cortex and subtylostyles as principal and intermediary spicules. The known area occupied by *P. arctica* is restricted only to the Barents and White Sea shelf. *P. euplectella* was synonimized with *P. robusta* by KOLTUN (1966). However it differs from the latter by the papilla length (20 - 50 mm in P. *euplectella* versus 2 - 8 mm in *P. robusta*), by the location of inhalant and exhalant canals in different papillae (while in *P. robusta* all papillae bear exhalant canals only) and by the presence of 3 spicule categories in the skeleton versus 2 in *P. robusta*. P. *euplectella* is known from the subtidal zone of the White and Barents Seas while *P. robusta* inhabits the NE Atlantic temperate waters from the littoral to the bathyal zone (BOURY-ESNAULT, 1987).

P. thielei was separated by KOLTUN (1964, 1966) from "*P. uberrima*" complex. It is a valid species differing from *P. uberrima sensu scripto* by the relatively low number of the papillae (usually less than 30 in P. *thielei versus* more than 30 in *P. uberrima*), by the presence of a separate vestibule layer in the cortex (while in *P. uberrima* small cortical vestibules are free scattered) and by the presence of choanosomal small tylostyles constituting a subcortical layer (while in *P. uberrima* the diffuse choanosomal skeleton is constituted by intermediary spicules and no subcortical layer is observed). P. *thielei* is widely spread in the Arctic from the Laptev Sea shelf in the East to the West Greenland where these sponges were found mainly in the bathyal zone. As to *P. uberrima* it is still considered to be a very polymorphic species or species complex, distributed from the NE Atlantic (BOURY-ESNAULT, 1987) to the Barents Sea and Polar Basin (KOLTUN, 1966). Unfortunately Schmidt's type specimen seems to be lost and its very short description hampers the revision.

P. grimaldi is undoubtedly a valid species widely spread from the Canadian Atlantic coast in the West to the Chuckchi Sea in the East. At the moment it is considered to be a *Polymastia,* but it shares several important characters with *Radiella*,

namely the radial growth pattern (only the central area of the basal surface is attached to the substrate), the different arrangement of upper and basal cortex, the presence of an edge spicule fringe and of 4 spicule categories in the skeleton. At the same time *P. grimaldi* shares with *P. arctica* the large number of papillae, the presence of a collagenous cortical layer and a subcortical tylostyle layer.

The validity of the two *Radiella* species found in Arctic mainly in the Greenland and Barents Sea is also evident. Both of them also inhabit the boreal Atlantic area. However it should be mentioned that northern specimens of *R. sarsi* were confused with *R. sol* by KOLTUN (1966). The status of the latter is still controversial but, according to the redescription of BOURY-ESNAULT (2002), the single specimen of *R. sol* identified by Schmidt possesses 15 papillae which do not correspond with *R. sarsi* definition.

Two species of *Sphaerotylus* are recognised in Arctic. It should be mentioned that the great variability of exotyle shape observed in *S. borealis* suggested SWARCZEWSKY (1906) and BOURY-ESNAULT (2002) to put this species in *Proteleia*. Nevertheless we follow herein KOLTUN (1966) who first placed "*borealis*" into *Sphaerotylus*. The latter possesses a two-layered cortex and its exotyles are never grapnel-like in contrast with *Proteleia* that is characterised by an additional palisade layer and grapnel-like exotyles (BOURY-ESNAULT, 2002). The status and relationships of all Polymastiidae with exotyles (*Sphaerotylus*, *Proteleia*, *Tylexocladus* etc.) should be reevaluated. However the shape of exotyle distal head seems to be a weak discriminating character if not supported by other ones.

The genera *Weberella* and *Tentorium* are both represented in the Arctic area by a single species. There is still no possibility to divide the widely spread species *T. semisuberites*. As to the genus *Quasillina* it seems reasonable to follow KOLTUN (1966) who considered the Arctic *Q. richardi* to be the junior synonym of the Atlantic *Q. brevis*. These species were discriminated only by the slight differences in the shape of the small styles (TOPSENT, 1913).

Summarising the data on the Arctic Polymastiidae it should be pointed out that the majority of species (with the exception of *P. arctica* and *P. euplectella*) inhabits both the Atlantic and the Arctic. The highest diversity of these sponges is registered in the Greenland, Norwegian and Barents Seas.

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