BIVALVES COLLECTED FROM THE BOTTOM OF THE PHILIPPINE TRENCH, INCLUDING A NEW SPECIES OF *AXINULUS* (THYASIROIDEA)

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Abstract *An account is given of two hadal bivalves obtained from box core and epibenthic sled samples taken from the bottom of the Philippine Trench between 9600m to 9807m. Additional data on the protobranch* Parayoldiella hadalis *are presented and a new species of Thyasiridae (*Axinulus philippinensis *sp. nov.) is described.*

Key words Parayoldiella, Axinulus, *Bivalvia, Philippine Trench, hadal, anatomy*.

INTRODUCTION

Life in the hadal zone (depths greater than 6000m) has recently been reviewed by Jamieson (2015) revealing that much of the available faunistic data dates back to expeditions of the mid twentieth century and that the taxonomy of many taxa was unresolved (Belyaev, 1969). Most research was carried out by Russia and Japan in the north-west Pacific while the Philippine Trench has seldom been investigated. Sampling of this trench was carried out, using various means, by the R/V Thomas Washington during the 1975 Eurydice Expedition under the leadership of Chief Scientist Dr. W Hessler of the Scripps Institute of Oceanography.

Despite the success of the sampling and photography, over a period from 24 February to 14 March 1975, remarkably few results have been published by the participants of the Expedition. Those that have been published include a paper on the scavenging amphipods by Hessler *et al.* (1978) and a more general and popularised account of the expedition by Wolff (1976). In addition an informal report and index of navigation, depth and magnetic data was prepared on 5 May 1975 by the Underway Data Processing Group of the Scripps Institution of Oceanography Geological Data Center.

The present paper records the bivalves taken by 7 successful sled and 16 successful box core samples from the trench floor at depths ranging from 9600m–9807m. Two main localities were sampled, one from a northern 'pond' at depths ranging from 9600m to 9609m and the other from a southern 'pond' at depths from 9803m to 9809m. Bivalves were present in 3 sled and 3 box core samples.

These were restricted to two species namely the protobranch *Parayoldiella hadalis* (Knudsen, 1970) and an undescribed species of Thyasiridae in the genus *Axinulus* sp. The latter is a new species herein described.

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MATERIALS

Samples containing bivalves were taken from two locations in the Philippine Trench at depths between 9600–9807 metres (Fig. 1, Table 1).

RESULTS

Subclass Protobranchia Pelseneer, 1889

Family Nuculanidae H & A Adams, 1858

Genus *Parayoldiella* Filatova, 1971

Type species *Yoldiella (Parayoldiella) ultraabyssalis* Filatova, 1971.

Paryoldiella hadalis (Knudsen 1970)
(Figs 2A–C)

Although described under the genus *Sarepta* Knudsen's species was transferred to *Parayoldiella* by Filatova & Schileyko (1985) and this is the accepted placement in WoRMS (Huber, 2015). Knudsen's specimens came from the Galathea Expedition and were some of the first hadal bivalves to be discovered, receiving immediate attention from Bruun, (1951) as *Portlandia*

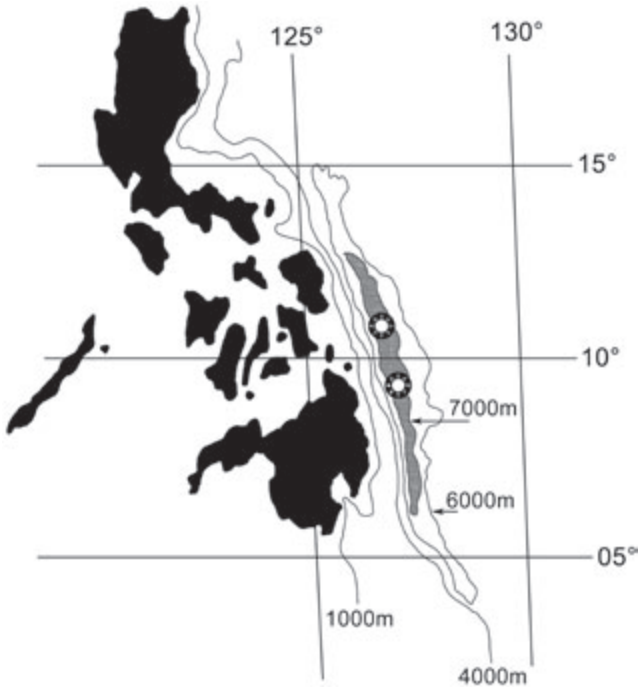


Figure 1 The position in the Philippine Trench floor of the two sampling sites containing bivalve specimens. The trench depth below 7000 metres is stippled and the position of the two sites indicated by stars.

sp. then by Wolff (1960) as *Glomus* sp. and by Belyaev (1966) as *Pristigloma* sp. *Parayoldiella*, as currently, defined is confined to a small group of eight hadal species, four of which have been recorded from the Philippine Trench (Filatova & Schileyko, 1985) (Table 2).

Identification

Shells of *Parayoldiella* are genrally rather featureless but most, to some degree, have a posterior ventral, marginal, sinus that in some is also expressed as an oblique keel or sulcus, notably in the type species *P. ultrabyssalis* Filatova 1971. This keeled form is well developed in only one of the species recorded from the Philippine Trench, *P. angulata* (Fig. 3a) but the marginal sinus is present in *P. inflata* (Fig. 3b) and *P. knudseni* (Fig. 3c). From the original figure of *P. hadalis*, (Knudsen, 1970, Fig. 5), also reproduced by Filatova & Schileyko, (1985), the marginal sinus and oblique sulcus are not apparent (Fig. 3d) but are noted in the written description. In the present material there is a weak marginal sinus but no apparent oblique sulcus. It is therefore possible that *P. hadalis* and *P. inflata* represent variation within a single species.

The Galathea specimen figured by Knudsen (1970, Fig. 5) is similar in outline to the largest specimens in the present samples. However the shape of the shell in lateral view changes somewhat with increasing length. Most noticeably, the postero-ventral margin of the smaller shells is somewhat less indented and the posterior half of the shell is not as broad as that figured by Knudsen (1970, Fig. 5).

Morphology

The present specimens fully confirm Knudsen's (1970) account of the morphology of the species which he recorded, it has been possible to add information on the variations in shell morphology and add a few more details on the soft part anatomy taken from specimens obtained by the Eurydice Expedition.

Length measurements were given for only three of the five specimens collected by the Galathea Expedition. The one figured, measures 5.4mm and two others recorded are 6–1 and 4.6mm. These three are of a similar size to the largest specimens collected by the Eurydice Expedition (Fig. 4) which range from 10mm upwards. The majority are in two groups (possibly year groups), which range in size from 1.0–1.9mm

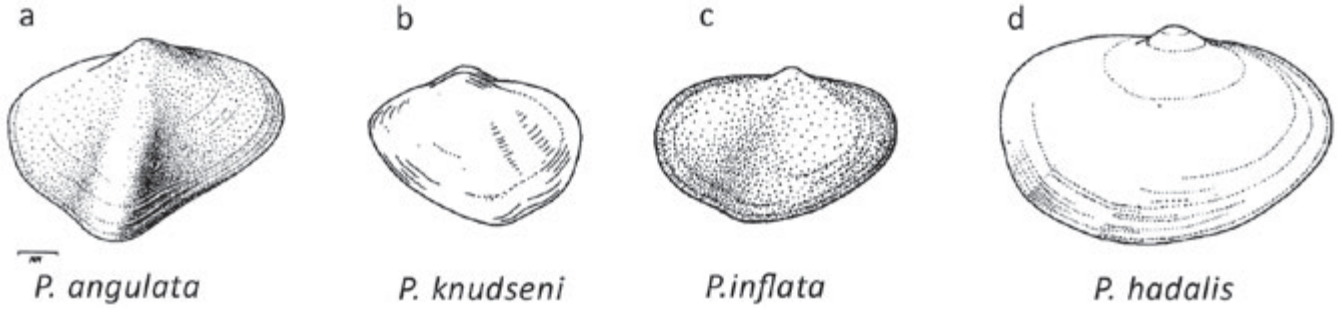
Table 1 Samples examined for this study

StationNo,	Location	Depth(m)	Taxon	No	Gear
175	10°37.6N 126°37.4E	9600	*Sarepta*	1	Sled
181	10°37.6N 126°37.3E	9605	*Sarepta*	29	Sled
189	10°35.8N 126°38.6E	9608	*Sarepta*	1	Box Core
			Axinulus	12	
193	10°38.0N 126°38.4E	9600	*Sarepta*	75	Sled
196	10°36.4N 126°37.9E	9605	*Sarepta*	2	Box Core
			Axinulus	18	
198	9°31.0N 127°34.0E	9807	*Sarepta*	3	Box Core
			Axinulus	49	

Figure 2 Size series of shells of *Parayoldiella hadalis* from the Eurydice Expedition, Philippine Trench, NHMUK 20130073.

Table 2 Species of Parayoldiella recorded from the Philippine Trench

Species	Location	Depth	Expedition	Type Locality
P. hadalis (Knudsen)	10°13'N 126°43'E	10,190–10,150m	Galathea 1951	Philippine T
P. knudseni Filatova & Schileyko	10°20'N 126°04'E	9820–10,000m	Galathea, 1951	Philippine T
P. angulata Filatova & Schileyko	10°23,7'N 126°43'E	8580–8400m	Vitiaz, 1975	Marianas T
P. inflata Filatova & Schileyko	10°21'N 126°38,8'E 10°23,7'N 126°43'E 10°23'N 126°35'E	9990–9980m 8580–8400m 9360–9390m	Vitiaz, 1975	Philippine T



Figures 3a–d Shells of four *Parayoldiella* species from the Philippine Trench (after Filatova & Schileyko, 1985).

and 2.1–3.5mm with only 13 specimens out of the total being larger. The difference in the sizes and numbers collected by the two expeditions are possibly due in part to the different areas sampled by the two expeditions and may also be due to the differences in sampling techniques. The Galathea Expedition used a surface trawl of unrecorded mesh size, while the Eurydice

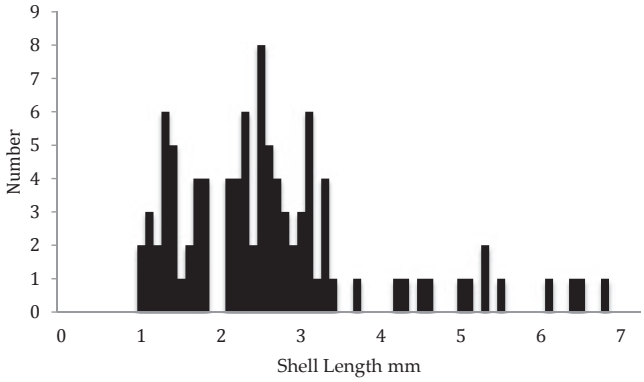
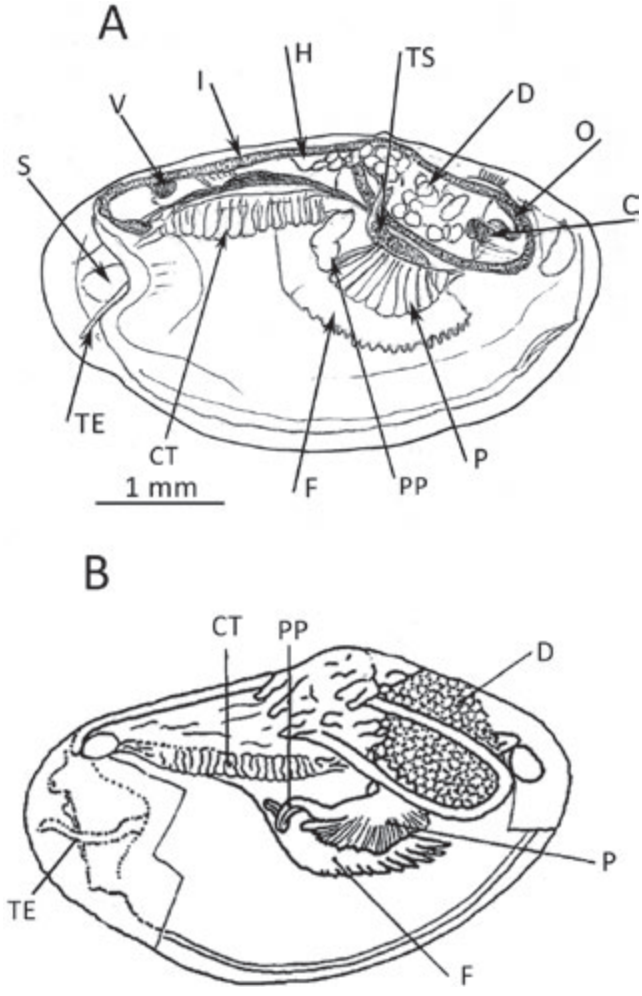


Figure 4 The size distribution of *Parayoldiella hadalis* taken in box core and sled samples from the trench floor.



Figures 5A Gross anatomy of *P. hadalis* from the Eurydice Expedition. **5B** Gross anatomy of *P. inflata* from the Vitiaz station 7202 *after Filatova & Schileyko, 1985*. Abbreviations: **C** cerebral ganglion; **CT** ctenidium; **D** digestive diverticula; **F** foot; **H** heart; **I** posterior intestine; **O** oesophagus; **P** palp; **PP** palp proboscides; **S** siphon; **TE** siphonal tentacle; **TS** testis; **V** posterior ganglion.

Expedition used a quantitative square box corer that sampled to a depth of approximately 60cm, as well as a surface sled.

A more detailed figure of the soft part anatomy than that given by Knudsen (1970) is included in this account (Fig. 5a). The only item of note is that the single siphonal tentacle is attached to the left side of the base of the siphon. The anatomy of *P. hadalis* was not illustrated by Filatova & Schileyko (1985) but there is considerable similarity with *P. inflata* (Fig. 5b), the only noticeable difference being the much longer finger-like palp proboscides.

Note: specimens from Station 198 have been lodged in the Natural History Museum, London – NHMUK 20130073. The remaining specimens have been returned to the Scripps Institute of Oceanography.

Subclass Heterodonta

Order Lucinoida Gray, 1854

Superfamily Thyasiroidea Dall, 1900

Genus *Axinulus* Verril & Bush, 1898

Type species *Cryptodon (Axinulus) brevis* Verrill & Bush, 1898.

Axinulus philippinensis sp. nov.
(Fig. 6)

Material examined

Holotype 1 specimen, Philippines Trench, Eurydice Expedition, station 198, 9°31.0N 127°34.0E, 9807m, NHMUK 20130074.

Paratypes 3 specimens as holotype NHMUK 20130075.

Other specimens have been returned to the Scripps Institution of Oceanography.

Description

Shell Shell small, largest shell collected measures 3.2mm in total length with the great majority measuring between 0.5mm and 1.5mm (Fig. 7). The shell is fragile, white, with the majority of specimens having variable degrees of a black coating. The shell is equivalve, oblique in shape with the length of smaller specimens somewhat exceeding the height but, as size increases,

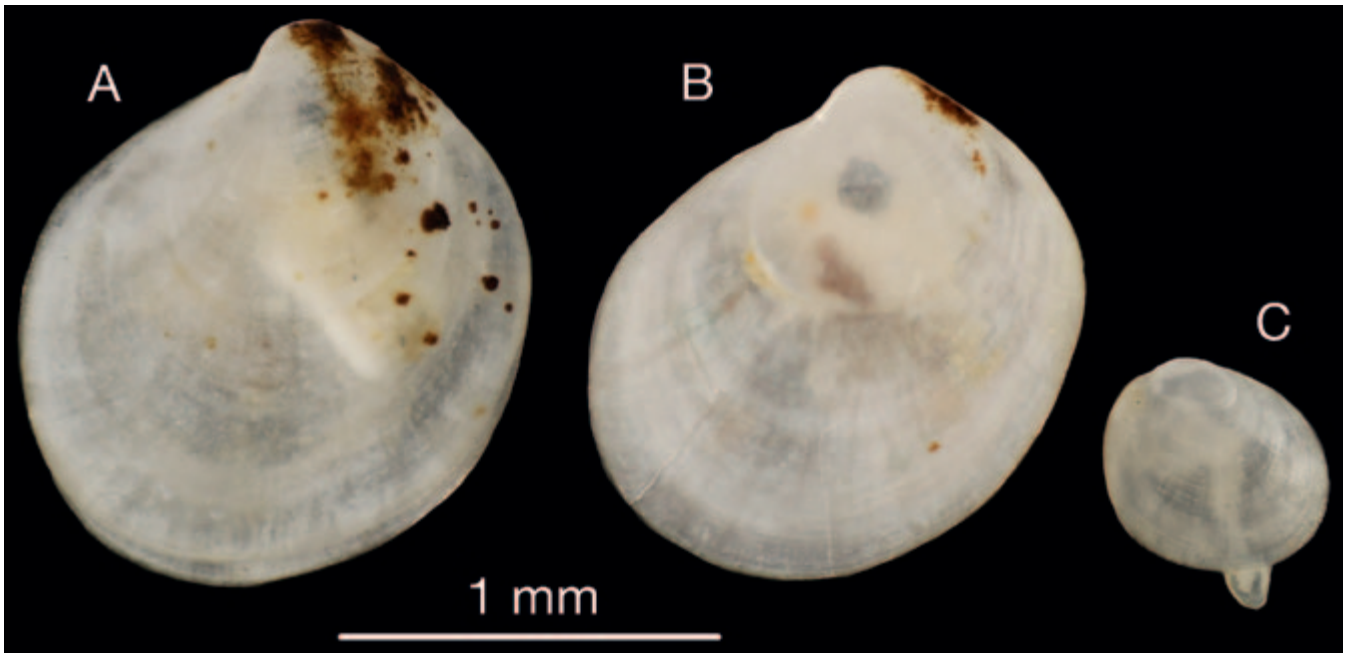


Figure 6 *Axinulus philippinensis* n. sp. **A** holotype NHMUK 20130074; **B–C** paratypes NHMUK 20130075.

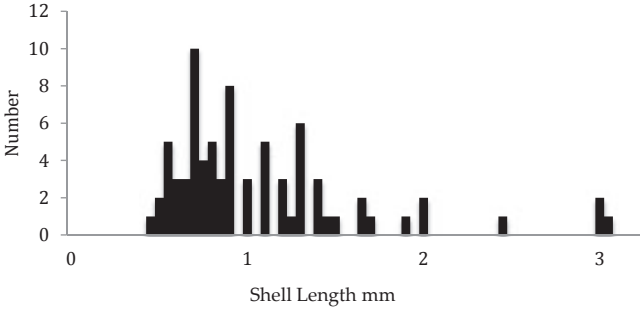


Figure 7 The size distribution of *Axinulus philippinensis* taken in box core samples from the trench floor.

this is reversed (Fig. 8). Furthermore, in the case of the largest specimens, the outline becomes more angular and the antero-dorsal margin becomes somewhat indented. A few growth lines are present and in a minority of specimens marginal radial lines of varying quantity are present (Figs 6, 8). Internally, the shell is of the simplest design. Apart from thickened valve margins in the region of the umbo there are no hinge teeth or ridges. The valves are joined at the umbo by an elongate simple ligament and fused periostracum. The ligament when viewed internally (Fig. 9) is posteriorly rounded and thickened, while anteriorly it is tapered and split between the two shell valves. Posteriorly the fused periostracum extends for a length similar to that of the ligament, while anteriorly it bridges the split section of ligament but is not fused beyond the ligament.

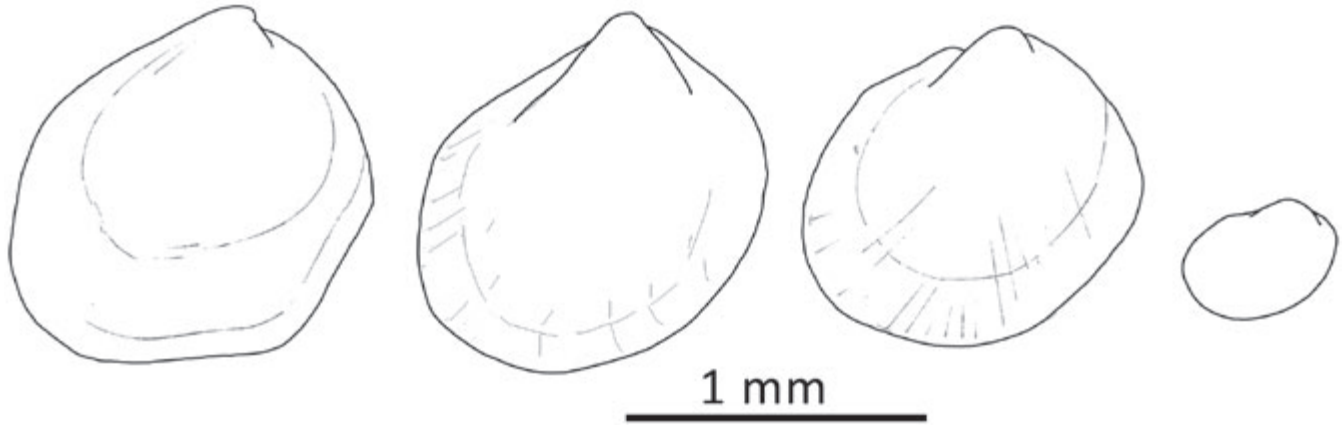


Figure 8 Outlines of the left valves of various sized specimens of *Axinulus philippinensis* to show the variation in shell shape. Note a few specimens have external radial markings at the shell edge. Scale=1.0mm.

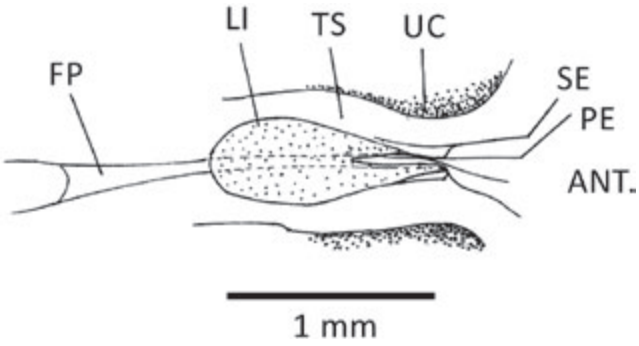
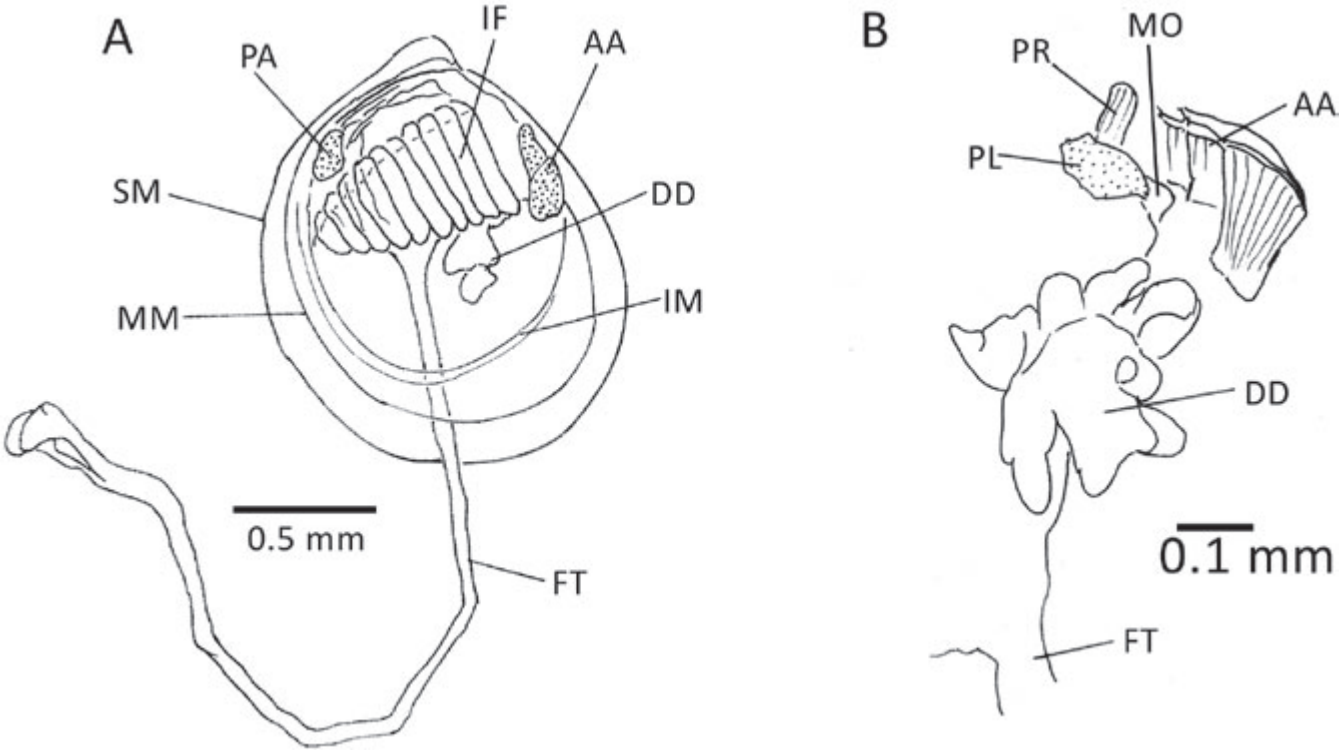


Figure 9 Internal view of the hinge of *Axinulus philippinensis.* Abbreviations: FP, fused periostracum; LI, ligament; PE, periostracum; SE, shell edge; TS, thickened shell margin; UC, umbonal cavity.

Anatomy The internal anatomy (Figs 10A–B) is very similar to other species of *Axinulus* that were described in detail by Payne & Allen (1991). Major differences include smaller inner demibranchs with shorter and fewer filaments than species from shallower water such as *A. brevis.* Furthermore the individual filaments are much shorter and thicker than those from lesser depths. As in other species, the foot can be extended to a considerable length (note the foot in Fig. 10A is curled in a posterior direction which is doubtless due to the fixation process). It should also be noted that the tip of the foot is more elongate than that of shallower water species (Payne & Allen, 1991) with a bilateral format not seen in other species (e.g *A. brevis).* Of other external anatomical items the palps (Fig. 10B) are very small, however, this is also true of previously recorded species.

Distribution Specimens were recorded from three box core samples taken from the base of the Philippine Trench at stations 189, 196 and 198 (see above). Note that this species is only recorded from the box core samples. It must be assumed that this relates to the depth at which this species of *Axinulus* occurs in the sediment and this is well below that reached by the sled. Note that the box core samples reached a depth of approximately 50cm below the surface of the sediment, thus explaining why it was not recorded by the Galathea expedition.



Figures 10A Gross internal anatomy of the right side of *Axinulus philippinensis.* Note the foot is unnaturally deflected posteriorly. **10B** Detailed anatomy of the anterior right side of *Axinulus philippinensis.* Abbreviations: **AA** anterior adductor; **DD** digestive diverticulum; **FT** foot; **IF** inner gill filaments; **IM** inner margin of mantle edge; **MM** mantle margin; **MO** mouth; **PA** posterior adductor; **PL** palp; **PR** anterior pedal retractor muscle; **SM** shell margin.

Comparisons The genus *Axinulus* is characterised by the small size, oval shell with poorly developed axial folds, ctenidium of a single demibranch, lateral body pouches with few lobes and elongate foot (Oliver, 2015).

Oliver (2015) considers that only three species can be assigned to this genus, *A. brevis* Verrill & Bush, 1898; *A. croulinensis* (Jeffreys, 1847) and *A. antarcticus* Zelaya, 2010. Comparisons with these reveals that *A. philippinensis* has a more quadrate shell and that the anatomy of the foot and ctenidium are unique to this species.

The absence of thickened muscle scars separates *Axinulus* species from *Genaxinus*. While WoRMS allocates more species to *Axinulus* the following have shell forms that are totally distinctive from *Axinulus*. *Axinulus careyi* Bernard, 1979 has the appearance of a *Mendicula*. *Axinulus hadalis* (Okutani, Fujikura & Kojima, 1999) is now more often referred to *Maorithyas* but this relatively large hadal species from the Japan Trench cannot be assigned to any current genus. *Axinulus thackergeigeri* Valentich-Scott & Coan, 2012 in Coan & Valentich-Scott, 2012 has a polygonal shell and also requires novel placement (Oliver, 2015).

Axinulus has been recorded from many other trenches (Belyaev, 1969) and are referred to as *Axinulus* n. sp. Filatova, but this taxon has never been formally described. Given the apparent endemism of many hadal taxa to individual trenches a complex of species of *Axinulus* may exist.

General Remarks

Apart from the general interest that bivalves can survive and breed in the deepest parts of the world's oceans, to date there are only ten species that have been recorded from the Philippine Trench (Belyaev, 1989). These are very small in size, the majority being 1 to 3mm in length and do not exceed more than 6mm in length. They belong to the commonest of all the groups that exist at abyssal depths and below namely, the Nuculanidae, Thyasiridae and Septibranchia (Allen, 2008). The deeper parts of the western Pacific are now better known. Although the Challenger Expedition of 1873–76 visited the region most of the samples were from relatively shallow water. The deepest exceptions being 530 from Stations 256 and 244 in the mid Pacific at depths of 5300m and 5400m (Smith, 1885 and Okutani, 1976). Thereafter results listing bivalve molluscs from hadal depths were those from the Russian Vitiaz Expeditions 1949–1959 (Filatova, 1958 & 1964 and Belyaev, 1966) and the Danish Galathea Expedition 1950–1952 (Knudsen, 1976). These were followed by Japanese Soyo-Maru cruises 1959 onward (Okutani, 1975). However, the Eurydice Expedition was only the second that sampled the Philippine Trench.

The two bivalve species reported from the Philippine Trench floor have not recorded elsewhere, particularly in trenches that are relatively close such as the Japanese Trench. Protobranch species of the genera *Spinula* and *Parayoldiella (S. bogorovi, S. vityazi, Parayoldiella idsubonini* and *Parayoldiella ultraabyssalis* all described by Filatova 1958 and 1964) have been recorded from other Pacific trenches. The thyasirid clams *Maorithyas hadalis* and *Parathyasira kaireiae* (both Okutani *et al.* 1999) have been reported from the Japan Trench at a depth of 7326m, but both differ greatly in terms of shell and soft part characters from *Axinulus philippensis.* It must be assumed that the water flows of the Philippine Trench and the length of time of the larval period, its movements and, possibly, physiological restrictions do not allow the spread of the species outwith the Trench.

Except for the length of the foot and the unusual form its tip in *Axinulus philippinensis*, the internal anatomy of the two species is not unusual compared with other species of their respective genera. That so many specimens were obtained from relatively few samples particularly considering the relatively small size of the box corer suggests that there is a plentiful food supply. This is probably related to the closeness of the Philippine Trench to the coast as compared with other Pacific trenches.

Acknowledgements

I would like to thank Dr Bob Hessler for his kindness in asking me to join the Eurydice Expedition. I would also like to thank my colleague Dr Fiona Hannah for her support and Dr Graham Oliver for supplying additional taxonomic data and images.

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