

Itheyaspira bathycodon new species (Vetigastropoda: Trochoidea: Turbinidae: Skeneinae) from the Von Damm Vent Field, Mid-Cayman Spreading Centre, Caribbean

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Itheyaspira bathycodon sp. nov. is described from the Von Damm Vent Field on the world's deepest spreading centre, the Mid-Cayman Spreading Centre (MCSC), Caribbean, at 2300 m depth. The new species is defined and illustrated from 11 specimens, with brief notes on habitat and known distribution. Molecular phylogenetic data from partial COI mtDNA, 16S rDNA and nuclear 18S rDNA regions are used to analyse the species' phylogenetic position and its morphology is compared with previously described skeneid and vent taxa. The new species is distinguished from the most closely allied vent species, *Itheyaspira lequios* Okutani, Sasaki & Tsuchida, 2000 by morphological differences in radula diagnosis and appendage structure of the head-foot. *Itheyaspira bathycodon* sp. nov. is the tenth turbinid to be described from a hydrothermal-vent environment and the second species to be named from recently discovered hydrothermal vents on the MCSC. Determining the faunal composition of assemblages at the vent fields of the MCSC will help to elucidate the vent biogeography of the region.

Keywords: Gastropoda, Vetigastropoda, Trochoidea, Turbinidae, Skeneinae, *Itheyaspira bathycodon*, new species, Cayman, hydrothermal vents

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INTRODUCTION

Gastropoda are one of the most species-rich macrofaunal taxa from hydrothermal vents (Warén *et al.*, 2006), and form a dominant component of assemblages at vent fields in western Pacific back-arc basins and on the Central and South-west Indian Ridges (e.g. Desbruyères *et al.*, 1994; Galkin, 1997; Kojima *et al.*, 2001; Van Dover *et al.*, 2001; Tao *et al.*, 2012). A substantial research effort has sought to elucidate the systematics and higher phylogeny of vent/seep gastropods and to characterize their diversity, biogeography and life-history biology (see Sasaki *et al.*, 2010 for recent review).

More than 200 species of gastropods from at least 100 genera and 35 families have been recorded from deep-sea chemosynthetic environments of the world's oceans (Sasaki *et al.*, 2010). Some of these species also inhabit non-chemosynthetic environments but have been recorded in much greater densities from chemosynthetic assemblages (see Sasaki *et al.*, 2010), but others are endemic to vents and seeps at the species and higher taxonomic levels (e.g. Warén & Bouchet, 2001).

Skeneinae Clark, 1851 was originally treated as a separate family ('Skeneidae') in Trochoidea Rafinesque, 1815 (e.g. Hickman & McLean, 1990). More recent anatomical

and molecular studies showed, however, that 'Skeneidae' was polyphyletic and that many genera should be reassigned (e.g. Bouchet *et al.*, 2005; Kano, 2008). Bouchet *et al.* (2005) ranked Skeneinae as a subfamily of the Turbinidae Rafinesque, 1815, an arrangement maintained by Williams *et al.* (2008) in the newly defined Turbinidae. The rank of the Skeneinae remains uncertain and is under discussion (Williams, in press).

To date, all turbinids endemic to deep-sea chemosynthetic environments belong to either the Skeneinae or the Margaritinae Thiele, 1924 (Sasaki *et al.*, 2010; see Table 1). Some colloniids, such as *Cantrainea* Jeffreys, 1883, also live in seeps and vents (e.g. Warén & Bouchet, 1993, 2001; Sasaki *et al.*, 2010). The family Colloniidae Cossmann, 1917 was classified as a subfamily within the Turbinidae (e.g. Hickman & McLean, 1990; Bouchet *et al.*, 2005), but was moved recently to familial rank in the superfamily Phasianelloidea Swainson, 1840 (Williams *et al.*, 2008).

The Von Damm Vent Field is an active, high-temperature hydrothermal system, situated in a unique off-axis setting on the upper slopes of an oceanic core complex at 2300 m depth (Connelly *et al.*, 2012). The Von Damm Vent Field supports an abundant faunal assemblage that is dominated by dense aggregations of the shrimp *Rimicaris hybisae* Nye, Copley & Plouviez, 2012 and includes small skeneimorph gastropods. During a recent research cruise to the Mid-Cayman Spreading Centre a piece of sulphide chimney was sampled from the Von Damm Vent Field. On the surface of the sampled sulphide

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Table 1. Turbinid gastropods described from extant hydrothermal vents/cold seeps up to the end of 2011 (confirmed locations and fully described species only).

Subfamily	Species	Site(s)	Depth (m)	Habitat	Primary references
Margaritinae	<i>Gaza fisheri</i>	GoM: Louisiana Slope; Caribbean Sea: off St Lucia	600–1061	Seep	Dall, 1889; Warén & Bouchet, 1993, 2001
	<i>Margarites huloti</i>	Off Central Chile (36°S)	843–728	Seep	Vilvens & Sellanes, 2006
	<i>Margarites ryukyensis</i>	OT: North knoll of Iheya Ridge	968–1053	Vent	Okutani, Sasaki & Tsuchida, 2000; Sasaki <i>et al.</i> , 2005
	<i>Margarites shinkai</i>	OT; SB	1110–1340	Vent/seep	Okutani, Tsuchida & Fujikura, 1992; Okutani <i>et al.</i> , 1992, 1993; Sasaki <i>et al.</i> , 2005
Skeneinae	<i>Bruceiella athlia</i>	Aleutian Trench	~4800	Seep	Warén & Bouchet, 2001; Kiel, 2004
	<i>Bruceiella globulus</i>	LB; NFB	1750–2443	Vent	Warén & Bouchet, 1993, 2001; Warén <i>et al.</i> , 2006
	<i>Bruceiella wareni</i>	CIR: Kairei	2422–2443	Vent	Okutani, Hashimoto & Sasaki, 2004
	<i>Fucaria mystax</i>	Edison Seamount	1483	Vent	Warén & Bouchet, 2001; Warén <i>et al.</i> , 2006
	<i>Fucaria striata</i>	JdFR: Middle Valley	2425	Vent	Warén & Bouchet, 1993; Warén & Bouchet, 2001; Warén <i>et al.</i> , 2006
	<i>Iheypira bathycodon</i> sp. nov.	MCSC: Von Damm	2300	Vent	This paper
	<i>Iheypira lequios</i>	OT: North knoll of Iheya Ridge	968–1053	Vent	Okutani, Sasaki & Tsuchida, 2000
	<i>Protolira thorvaldssoni</i>	MAR: Menez Gwen to Snake Pit & Ashadze; off south-western Iceland	850–4080	Vents and whale bone	Warén, 1996; Warén & Bouchet, 2001; Warén <i>et al.</i> , 2006; Fabri <i>et al.</i> , 2011
	<i>Protolira valvatoides</i>	MAR: Menez Gwen to Lucky Strike, Snake Pit	850–3478	Vent	Warén & Bouchet, 1993, 2001; Warén <i>et al.</i> , 2006

CIR, Central-Indian Ridge; GoM, Gulf of Mexico; JdFR, Juan de Fuca Ridge; LB, Lau Basin; MAR, Mid-Atlantic Ridge; MCSC, Mid-Cayman Spreading Centre; NFB, North Fiji Basin; OT, Okinawa Trough; SB, Sagami Bay.

chimney were several small gastropods of one species, *Iheypira bathycodon* sp. nov., which is described herein. In addition to enhancing existing knowledge about biodiversity, characterizing the composition of faunal assemblage at Mid-Cayman Spreading Centre vents has the potential to elucidate the factors determining vent biogeography of this region.

MATERIALS AND METHODS

Specimens were collected from the Von Damm Vent Field (2300 m) at the Mid-Cayman Spreading Centre, Caribbean, during the 44th voyage of RRS 'James Cook' (April 2010). All specimens were picked from the surface of a sample of sulphide chimney, collected by the hydraulic grab of HyBIS (Hydraulic Benthic Interactive Sampler), a manoeuvrable TV grab sampler. Specimens for molecular analysis were immediately placed in 100% ethanol and the shell and operculum were subsequently removed. Specimens for morphological study were fixed in 10% neutralized formalin, subsequently transferred to 90% Industrial Methylated Spirits and measured to the nearest 0.1 mm using Vernier callipers (see Table 2).

Specimen [NHMUK 20120076] was dissected for scanning electron microscopy (SEM) of shell, operculum and radula. The shell and operculum were placed in an ultrasonic cleaning bath for three minutes. The mantle tissue was dissolved in potassium hydroxide diluted in water to expose the radula. The shell, operculum, radula and ctenidium were mounted uncoated onto an aluminium stub and micrographs were taken with a Hitachi TM3000 tabletop microscope. For SEM of soft parts, specimen [NHMUK 20120070] was dehydrated through a graded ethanol series, critical point

dried and sputter coated with gold palladium prior to examination with a FEI Quanta 200 scanning electron microscope at accelerating voltage of 10 kV.

Genomic DNA was extracted from eight specimens using the cetyltrimethyl ammonium bromide (CTAB) extraction procedure (Doyle & Dickson, 1987). A region of mitochondrial cytochrome oxidase subunit I gene (COI) was amplified by polymerase chain reaction (PCR) performed in 20 µl final volume using universal primers (Folmer *et al.*, 1994) and the following conditions: 1X buffer reagent (200 mM Tris pH 8.8, 500 mM KCl, 0.1% Triton X-100, 2 mg/ml bovine serum albumen), 2 mM MgCl₂, 0.2 mM of each dNTP, 0.5 mM of each primer, 1 U Taq DNA polymerase (Bioline), 5 µl of template DNA and sterile H₂O to final volume. Thermal cycling conditions were: 94°C/2 minutes; followed by 5 cycles at (94°C/35 seconds; 45°C/35 seconds; 72°C/1:20 minutes) and 35 cycles at (94°C/35 seconds; 50°C/35 seconds; 72°C/1:20 minutes) with a final extension of 72°C/10 minutes.

For the 16S ribosomal DNA gene (16S), PCR amplifications were performed in 20 µl final volume using 16Sar and 16Sbr primers (Palumbi, 1996) and the following conditions: 1X buffer reagent (same as for COI), 2.5 mM MgCl₂, 0.13 mM of each dNTP, 0.38 mM of each primer, 1 U Taq DNA polymerase (Bioline), 2.5 µl of template DNA and sterile H₂O to final volume. Thermal cycling conditions were: 94°C/4 minutes; 30 cycles at (94°C/30 seconds; 52°C/1 minute; 72°C/2 minutes) and 72°C/5 minutes.

Polymerase chain reaction amplifications of the 18S ribosomal DNA gene (18S) were performed using the primer pair 5'-CACAGTGAACTGCGAATGG-3' and 5'-CAAATGCTTTCGCTGTAGGG-3' (this study) in a 20 µl final volume amplification mixture as described for COI. Thermal cycling

Table 2. Morphological variation in *Iheyaspira bathycodon* sp. nov.

Catalogue no.	Type status	Shell height (mm)	Shell diameter (mm)	No. whorls	Operculum diameter (mm)	Operculum no. rings
NHMUK 20120068	Holotype	4.3	3.6	4.3	1.8	11
NHMUK 20120069	Paratype	6.7	5.9	4.5	1.8	11
NHMUK 20120070**	Paratype	5.2	4.3	4.5	2.1	13
NHMUK 20120071	Paratype	5.4	5.1	4.2	1.8	14
NHMUK 20120072	Paratype	5.9	5.5	4.3	2.2	17
NHMUK 20120073	Paratype	4.8	4.2	4.3	2.3	12
NHMUK 20120074	Paratype	3.7	3.6	3.6	1.4	9
NHMUK 20120075*	Paratype	6.9	5.6	4.6	3.3	16
NHMUK 20120076**	Paratype	6.7	6.5	4.6	2.6	13
NHMUK 20120077	Paratype	6.4	5.0	4.6	2.5	14
NHMUK 20120078	Paratype	7.2	6.1	4.4	2.8	14

*, soft parts dissected out of shell; **, soft parts dissected out of shell and used for scanning electron microscopy.

conditions were: 95°C/5 minutes followed by 30 cycles at (94°C/1 minute; 60°C/1 minute; 72°C/2 minutes; 72°C/2 minutes).

Purifications and sequencing were performed as described by Nye *et al.* (2012). Sequence strands were proofread and assembled with CodonCode Aligner, version 3.7.1 (CodonCode Corporation, Dedham, MA, USA), to produce a continuous fragment. The 16S and 18S partial rDNA sequences were compared with those of other gastropods available in GenBank using the BLAST program (NCBI Basic Alignment Search Tool). The COI partial sequence of the new species was also compared with those of other trochoids of Suzanne Williams's published and unpublished dataset of deep-sea gastropods (Williams *et al.*, 2008; S. T. Williams, personal communication). Phylogenetic trees were constructed with MEGA5 (Tamura *et al.*, 2011) using both maximum-likelihood (ML) (Kimura, 1980) and neighbour-joining (NJ) (Saitou & Nei, 1987) methods on 425- and 803-base pair (bp) alignments for 16S and 18S respectively. Bootstrap values were calculated on 1000 re-sampling replicates.

The GenBank accession numbers for the partial sequences of COI, 16S and 18S regions from the new species are JQ306326, JQ306327 and JQ306328 respectively.

SYSTEMATICS

Order VETIGASTROPODA Salvini-Plawen, 1980

Superfamily TROCHOIDEA Rafinesque, 1815

Family TURBINIDAE Rafinesque, 1815

Subfamily SKENEINAE Clark, 1851

Genus *Iheyaspira* Okutani, Sasaki & Tsuchida, 2000

Iheyaspira bathycodon sp. nov. Nye, 2012

(Figures 1–5)

TYPE MATERIAL

Holotype and paratypes deposited in the Natural History Museum, UK (NHMUK) [NHMUK 20120068–20120078]. All type material collected from the surface of a piece of sulphide chimney sampled from the Von Damm Vent Field, Mid-Cayman Spreading Centre, Caribbean (18° 22.605'N 81° 47.875'W), water depth 2300 m.

DESCRIPTION

Shell (Figure 1). Rounded, skeneiform, sturdy, height greater than width (see Table 2); maximum dimensions 7.2 mm

height, 6.1 mm width [NHMUK 20120078]. Surface smooth, lacking pigmentation, with thin, beige-white periostracum. Surface and apical region, including the protoconch and early teleoconch, are corroded in most specimens. Protoconch too corroded for any details to be seen (Figure 1 E, F). Teleoconch whorls more than 2.5 in number, body whorl large. No nacre or lustre visible on exterior or interior of the shell. Umbilicus open and deep, clearly visible in basal view. Peristome smooth. Aperture large and circular with smooth outer lip.

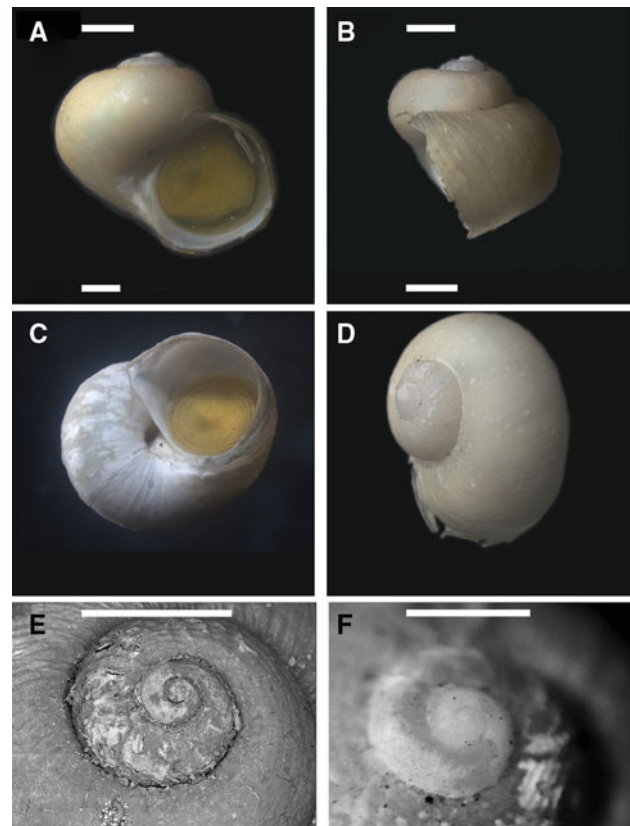


Fig. 1. *Iheyaspira bathycodon* sp. nov., shell, from the Von Damm Vent Field, Mid-Cayman Spreading Centre, Caribbean, 2300 m. (A) Holotype [NHMUK 20120068]; (B) holotype, lateral view [NHMUK 20120068]; (C) holotype, basal view [NHMUK 20120068]; (D) paratype [NHMUK 20120072]; (E) holotype, apical view [NHMUK 20120068]; (F) holotype, sub-apical view [NHMUK 20120068]. Scale bars: A–F = 1 mm.

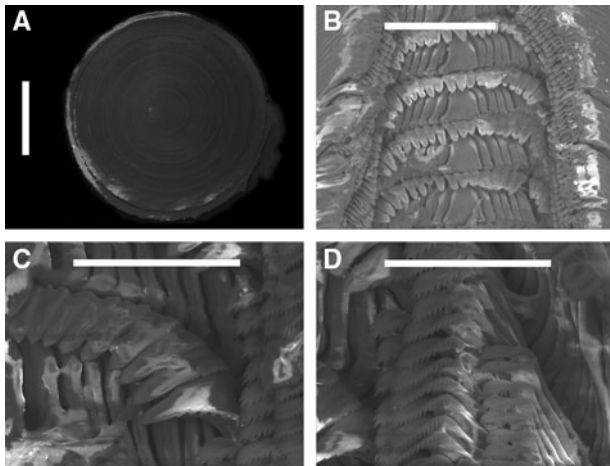


Fig. 2. *Theyaspira bathycodon* sp. nov., paratype 08 [NHMUK 20120076] from the Von Damm Vent Field, Mid-Cayman Spreading Centre, Caribbean, 2300 m. (A) Operculum; (B) radula; (C) radula: lateral teeth; (D) radula: marginal teeth. Scale bars: A = 1 mm; B = 100 μ m; C, D = 50 μ m.

Operculum (Figure 2A) moderately thin, corneous, and yellowish-brown; multispiral with a central nucleus and short growing edge, with a good fit to the aperture. Opercula retraction is deep.

Soft parts (Figures 3–5). Animal pale white in colour. Head quite large, snout cylindrical, terminating in a broad tip with mouth positioned at the midline. One pair of cephalic tentacles of similar size to each other and equal in length to the snout; cephalic tentacles densely papillate with what appear to be sensory papillae (Figure 5D). Eyestalks subequal in length and width to cephalic tentacles, without visible papillae and eyes. Right eyestalk approximately one-half length of right cephalic tentacle (Figure 4A, B, D), left eyestalk approximately one-third length of left cephalic tentacle (Figure 5A, B). Cephalic lappets absent. Neck lobes arise from both basal sides of the head. Right neck lobe (Figure 4D) divided into

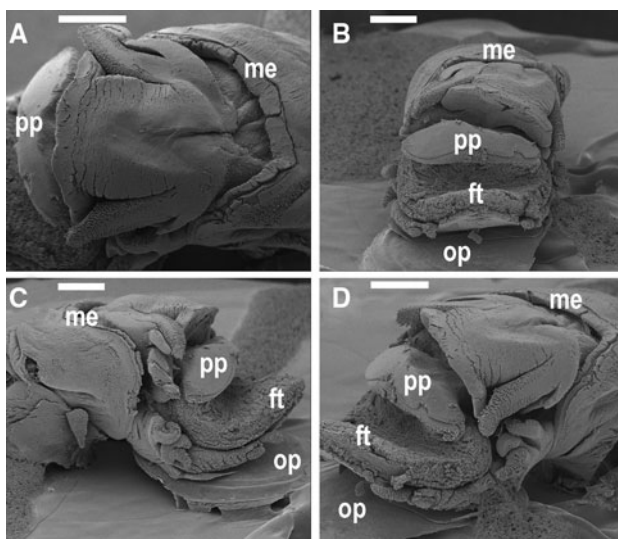


Fig. 3. *Theyaspira bathycodon* sp. nov., paratype 02 [NHMUK 20120070] from the Von Damm Vent Field, Mid-Cayman Spreading Centre, Caribbean, 2300 m. Scanning electron microscopy micrographs of head-foot. (A) Dorsal view; (B) anterior view; (C) right side, lateral view; (D) left side, anterolateral view. Abbreviations used: ft, foot; me, mantle edge; op, operculum; pp, parapodium. Scale bars: A = 1 mm; B–D = 500 μ m.

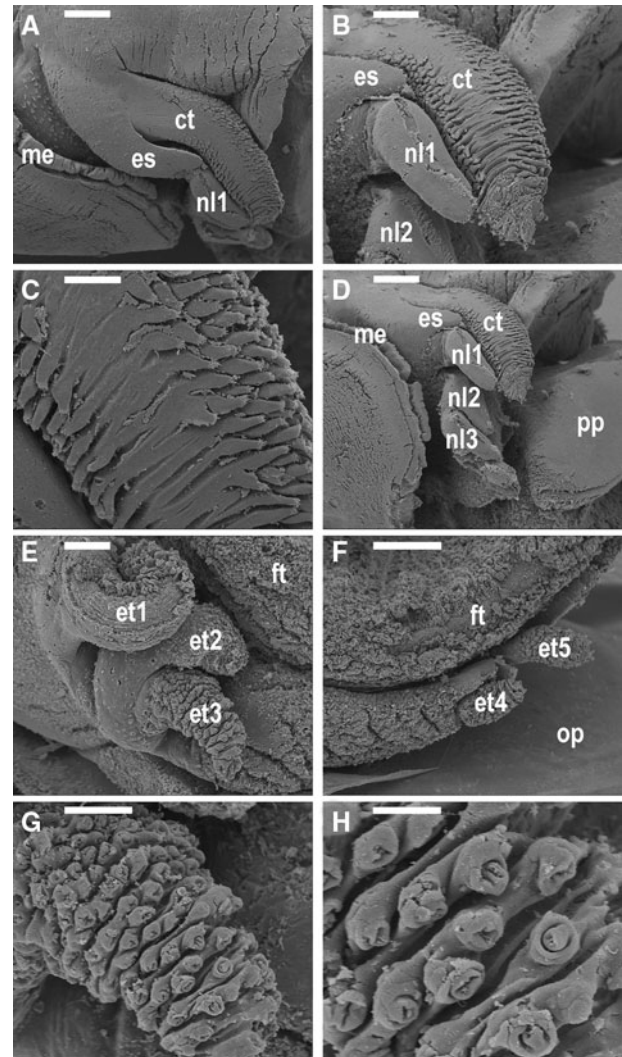


Fig. 4. *Theyaspira bathycodon* sp. nov., paratype 02 [NHMUK 20120070] from the Von Damm Vent Field, Mid-Cayman Spreading Centre, Caribbean, 2300 m. Scanning electron microscopy micrographs of head-foot, right side. (A) Head, dorsolateral view; (B) head appendages, anterolateral view; (C) close-up of cephalic tentacle, lateral view; (D) head appendages and neck lobes, anterolateral view; (E) epipodial tentacles 1–3, dorsolateral view; (F) epipodial tentacles 4–5, lateral view; (G) epipodial tentacle 3, anterolateral view; (H) papillae on epipodial tentacle 3. Abbreviations used: ct, cephalic tentacle; es, eyestalk; et, epipodial tentacle; ft, foot; me, mantle edge; nl, neck lobe; op, operculum; pp, parapodium. Scale bars: A, D, F = 200 μ m; B, E = 100 μ m; C, G = 50 μ m; H = 20 μ m.

elongate anterior (nl1) and posterior (nl2, nl3) tentacles. Left neck lobe composed of at least one undivided tentacle beneath the left eyestalk (Figure 5A, B). Foot equipped with five epipodial tentacles on both sides. Right side: first, second and third epipodial tentacles clustered together, similar in size, with dense papillae except on second (Figure 4E); fourth and fifth isolated from first three in middle part of epipodium between lobes of epipodial skirt, densely papillate (Figure 4F). Left side: first, second and third epipodial tentacles clustered together; first and third epipodial tentacles of similar size with dense papillae; second slightly smaller, without visible papillae (Figure 5E); fourth and fifth isolated from first three in middle part of epipodium, densely papillate (Figure 5F). Ctenidium monopectinate, attached along its whole length, with bursicles.

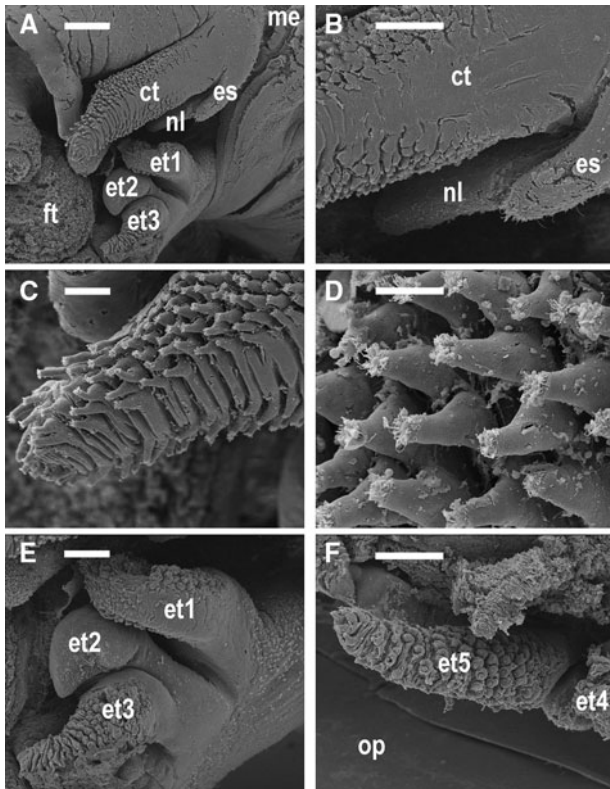


Fig. 5. *Iheyaspira bathycodon* sp. nov., paratype 02 [NHMUK 20120070] from the Von Damm Vent Field, Mid-Cayman Spreading Centre, Caribbean, 2300 m. Scanning electron microscopy micrographs of head-foot, left side. (A) Head, dorsolateral view; (B) head appendages, lateral view; (C) tip of cephalic tentacle, lateral view; (D) papillae on cephalic tentacle; (E) epipodial tentacles 1–3, dorsolateral view; (F) epipodial tentacles 4–5, dorsolateral view. Abbreviations used: ct, cephalic tentacle; es, eyestalk; et, epipodial tentacle; ft, foot; me, mantle edge; nl, neck lobe; op, operculum. Scale bars: A = 200 μ m; B, E, F = 100 μ m; C = 50 μ m; D = 20 μ m.

Radula (Figure 2B, D). Rhipidoglossate, bilaterally symmetrical, with the formula $\infty -9 -1 -9 -\infty$ (>20). Length ~ 3.1 mm, width ~ 384 μ m, with at least 60 transverse rows along total length in paratype 08 [NHMUK 20120076]. Central tooth differentiated in form from lateral teeth; smooth-sided, bell-shaped, wider proximally than distally, with a single incurved central cusp (Figure 2B). Lateral teeth (Figure 2B, C) of similar size to central tooth, increasing in size outwards; with a long, rounded single central cusp, and an outer apical margin with several flanking denticles (>7); dentition attenuates towards the cusp and is strongest on the outermost lateral. Marginal teeth (Figure 2B, D) exceed twenty in number on both sides; cutting plate concave, terminating in a single short cusp; apical margins oblique, each with about 10–14 denticles that are longer and finer than those on the lateral teeth. Outermost marginal teeth in a row are smaller, with weaker dentition and straighter shafts. Marginal rows overlap each other.

No jaws are present.

COMPARATIVE REMARKS

The shell of *Iheyaspira bathycodon* sp. nov. is superficially similar to those of several other skeneimorph taxa, but the radula pattern appears to be unique in both number of teeth and shape.

The new species is closest in morphology to *Iheyaspira lequios* Okutani, Sasaki & Tsuchida, 2000 (Turbinidae: Skeneinae), the type species of a monotypic genus. Affinities with *I. lequios* include conchological similarity and shared radula characters, most notably in the shape of the central tooth (see Okutani *et al.*, 2000: Figure 2, p. 269). The new species does however exhibit several important dissimilarities to *I. lequios*: (1) shell: small (maximum 7.2×6.1 mm) rather than minute (maximum 5.7×5.4 mm in *I. lequios*), umbilicate, teleoconch with more than two whorls; (2) radula: central tooth bell-shaped, not rhombic/arrow-shaped; only nine (not twelve) pairs of lateral teeth; (3) eyestalks: reduced, subequal in length and width to cephalic tentacles, as opposed to well-developed, thicker than cephalic tentacles; (4) neck lobes: right neck lobe composed of three (not two) tentacles; (5) epipodial tentacles: five (not four) on both sides; left ET1 and ET3 densely papillate (*I. lequios* ET1–3 lack papillae). In *Iheyaspira bathycodon* sp. nov., ET2 and ET3 are very close together, arising as a pair from the same base; this is similar to *I. lequios*, and may be an epipodial sense organ.

The new species is also comparable with the turbinid *Fucaria mystax* Warén & Bouchet, 2001 (Skeneinae), based on similarities in shell and radula characters, especially the shape of the central tooth (see Warén & Bouchet, 2001: Figure 11C, p. 135). *Iheyaspira bathycodon* sp. nov. is differentiated from *F. mystax* by: (1) shell: umbilicus clearly visible in basal view, teleoconch with greater number of whorls (>2.5); (2) radula: central tooth bell-shaped, lacking drawn out and narrow anterior support; only nine (not eleven) pairs of lateral teeth; (3) eye stalks: do not encircle cephalic tentacles. Moreover, members of the genus *Fucaria* Warén & Bouchet, 1993 are equipped with a coat of sensory papillae on the snout, a feature not observed in the new species.

DISTRIBUTION AND HABITAT

Known only from the type locality, the Von Damm Vent Field, Mid-Cayman Spreading Centre, Caribbean in 2300 m depth. See Connelly *et al.* (2012) for a description of the geological, geochemical and biological setting of the Von Damm Vent Field. Accompanying fauna observed in close proximity to the new species included the alvinocaridid shrimps *Rimicaris hybisae* Nye, Copley & Plouviez, 2012 and *Alvinocaris* sp., the hippolytid shrimp *Lebbeus* sp., zoarcid fish and siboglinid polychaetes.

ETYMOLOGY

The species name *bathycodon* is derived from the Greek words for deep and bell, in reverence to the species' deep-sea habitat and bell-shaped rachidian tooth.

MOLECULAR PHYLOGENY

Partial sequences of the COI (549 bp), 16S (505 bp) and 18S (803 bp) region of *Iheyaspira bathycodon* sp. nov. were consistent amongst specimens. Fixed and unique mutations were observed in the partial sequences of the COI, 16S and 18S regions in comparison with other trochoid taxa. When compared with partial sequences of COI in the gastropod dataset of Suzanne Williams (NHMUK) the partial COI sequence of the new species was near other trochoidean skeneimorph taxa and unique amongst any of the species available (Suzanne Williams, personal communication). Based on a 425-bp alignment of partial 16S sequences, NJ and ML

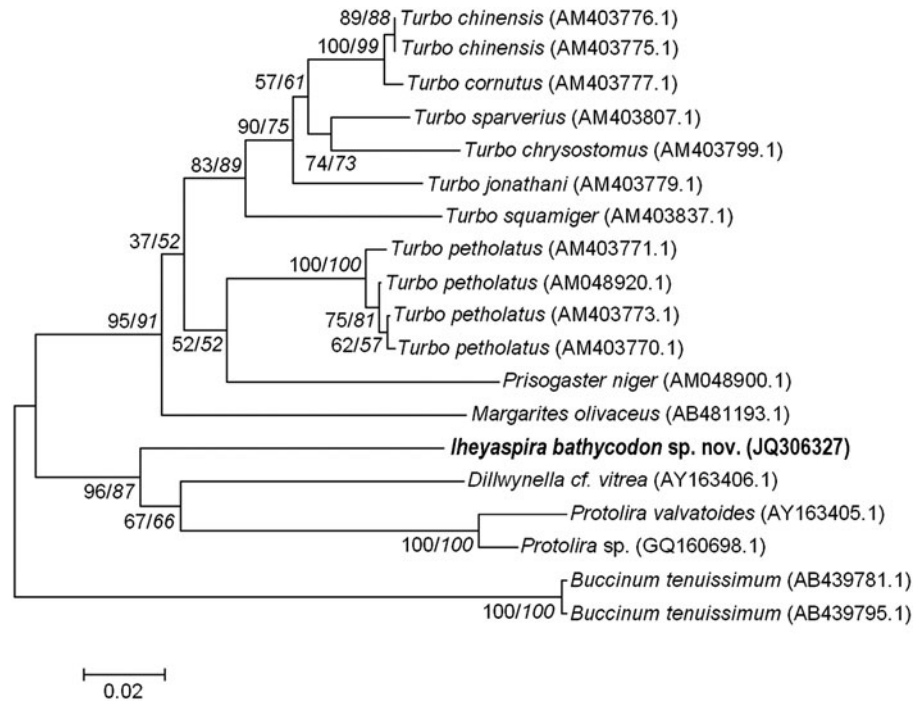


Fig. 6. Neighbour-joining tree of turbinid gastropods based on a 425-bp alignment of partial nucleotide sequences from the mitochondrial 16S region with *Buccinum tenuissimum* (Caenogastropoda: Neogastropoda: Buccinoidea: Buccinidae) as outgroup. Evolutionary distances computed using the Jukes–Cantor method (Jukes & Cantor, 1969) are represented by branch length; scale bar is proportional to inferred nucleotide divergence. Bootstrap support calculated on 1000 re-sampling replicates is shown by the numbers along the branches (NJ, plain text; ML, italic text). GenBank accession numbers are given after species names.

phylogenetic trees have the same topologies and place the new species in the same clade (Turbinidae: Skeneinae) as *Dillwynella* cf. *vitrea* [AY163406.1], *Protolira valvatoides* [AY163405.1] and *Protolira* sp. [GQ160698.1], with 96% and 87% bootstrap support for NJ and ML methods respectively (Figure 6). Of the 16S partial sequences available in GenBank the new species is closest in evolutionary distance to *D. cf. vitrea* (14% divergence). Phylogenetic analyses on an 803-bp alignment of partial 18S sequences of turbinid species place the new species closest in evolutionary distance to *D. planorbis* [AB365310.1], with 39% and 42% bootstrap support for NJ and ML methods respectively. The new species exhibits 1.4% divergence from *D. planorbis* across an 803 bp of the 18S region.

DISCUSSION

The molecular and morphological analyses of specimens of this trochoid gastropod reveal the presence of a new species. The new species is similar in morphology to *Iheyaspira lequios* and *Fucaria mystax* (see above), both of which are known only from hydrothermal vents in the Pacific at water depths less than 1500 m (see Table 1). It is, however, excluded from both species by differences in the radula and appendage structure of the head-foot (see above). It is closest in morphology to *I. lequios* and, therefore, the most conservative approach is to give the new species the generic name *Iheyaspira* to indicate the similarity between the two species. Consistency between specimens of *I. bathycodon* sp. nov. in partial sequences of the COI, 16S and 18S regions confirm that they belong to a single species, but the presence of unique and fixed mutations in the sequences indicate that

they are genetically distinct from all other genera and species in the GenBank database.

The systematic position of both *Iheyaspira* and *Fucaria* is uncertain because there are no sequences available in GenBank for either genus; however both genera are classified currently within the family Turbinidae and subfamily Skeneinae (e.g. Bouchet, 2010 a, b; Sasaki *et al.*, 2010). After redefining the Turbinidae, Williams *et al.* (2008) remarked that it is hard to determine morphological characters that are typical of this family, and even suggested that the Skeneinae could be considered as a group distinct from (but most closely related to) Turbinidae (Williams *et al.*, 2008). The rank of the Skeneinae is still under discussion and further work will elucidate the systematic position of this taxon (Williams, in press).

Morphological features of the Skeneinae shared with the new species include the monopectinate ctenidium and absence of any visible nacre. In addition, the shell of the new species bears superficial resemblance to that of other members of the Skeneinae, such as *Protolira*. In the GenBank database sequences for the Skeneinae are available presently for a few species only. Despite this impediment, comparative 16S results presented herein suggest the proximity of the new species to members of the Skeneinae, with strong bootstrap support for inclusion of the new species within this clade. This is further supported by comparative 18S results, whereby NJ and ML methods both place the new species closest in evolutionary distance to *Dillwynella planorbis* [AB365310.1], although this is with weak bootstrap support (39% and 42% for NJ and ML methods respectively).

The first right neck lobe tentacle (RNL1) in the new species may be modified (see Figure 4 B, D). Warén & Bouchet (1989) described a modified neck lobe tentacle in *Bathymargarites*

symplector Warén & Bouchet 1989 and interpreted this modified appendage as a penis. Collection of further specimens will enable the reproductive anatomy of the new species to be characterized.

The recent discovery of hydrothermal vents and chemosynthetic assemblages on the Mid-Cayman Spreading Centre has provided an opportunity to enhance existing knowledge about biodiversity in the deep sea. *Iheyaspira bathycodon* sp. nov. is the second new species to be described from the Von Damm Vent Field, and the tenth turbinid gastropod to be described from a hydrothermal vent environment to date (Table 1). Description of species from Mid-Cayman Spreading Centre vents, and further characterization of their faunal assemblages by future collections has the potential to elucidate the factors determining vent biogeography of this region.

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