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ORIGINAL PAPER

A new species of Glyceridae (Annelida: "Polychaeta") recovered from organic substrate experiments at cold seeps in the eastern Mediterranean Sea

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Abstract A new species of Glyceridae, *Glycera noelae* sp. nov., was recovered from two distinct colonization experiments based on organic substrates, deployed for 1 year at cold seeps in the eastern Mediterranean Sea (1,694 m depth, Nile Deep-Sea Fan Central Site 2A). The new taxon, which is the first glycerid reported from such an environment, is described by using morphological and molecular methods (18S rDNA, 16S rDNA, COI, ITS1, ITS2).

Keywords Annelida · Glyceridae · Deep sea · Cold seeps · Mediterranean sea · New species

Introduction

Sunken wood, whale carcasses and kelp provide an input of concentrated, locally and temporally restricted packages of organic material to the deep sea. Even though these organic falls are unpredictable in time and space, they are yet quickly located and colonized by specialized opportunistic fauna (e.g. Smith et al. 1989; Dahlgren et al. 2004; Rouse et al. 2004; Pleijel et al. 2008; Wiklund et al. 2009; Gaudron et al. 2010) and can quickly develop into hot spots of biodiversity in deep-sea environments (Baco and Smith 2003). Intensive local degradation processes can lead to reducing conditions and high sulphide concentrations (Smith and Baco 2003; Laurent et al. 2009; Treude et al. 2009). Sunken wood ecosystems remain poorly understood, and the overall aim of the colonization experiments evoked in this paper is to contribute to a better understanding of diversity and biogeochemical gradients establishing at wood falls in the deep sea. Within the framework of these experiments a new glycerid species was discovered and is described in the following.

The Glyceridae Grube, 1850 are an easily recognizable group of polychaetes, because their pointed, usually annulated prostomium with two pairs of terminal appendages, and their long, muscular, eversible axial proboscis, which is densely covered with papillae and provided with four hook-shaped jaws and accessory lateral ailerons, are unique characters among the Annelida (Böggemann 2006a). Only the Goniadidae Kinberg, 1865 share some of these characters, but their jaws usually consist of two macrognaths and a variable number of dorsal and ventral micrognaths, and sometimes lateral rows of chevrons are also present (Böggemann 2006a). The glycerids have a worldwide distribution, from intertidal to abyssal depths (Böggemann 2002, 2009), and are generally considered to be carnivorous, capturing prey with their jaws and killing it by the injection of venom (Ockelmann and Vahl 1970; Fauchald and Jumars 1979; Manaranche et al. 1980). In most species, the animals form semi-permanent burrow systems in sandy or muddy sediments (Ockelmann and Vahl 1970), whereas a few occur free-living under rocks or

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crawling on algae (Fauchald and Jumars 1979). The specimens of *Glycera noelae* sp. nov. examined here were found in or on wood and grass substrates and therefore seem to be motile.

Material and methods

Specimens were recovered from two separate experiments carried out at the same cold seeps site in the eastern Mediterranean Sea (Fig. 1). Both experiments were deployed at the "Central Zone 2A" in the Nile Deep-Sea Fan (Dupré et al. 2007; Foucher et al. 2009) at a water depth of 1,694 m and for a duration of 1 year. Deployment was conducted with the ROV *Quest 4000* (MARUM, Bremen, Germany) during the BIONIL cruise (RV *Meteor* M70/2b) in November 2006; recovery took place during the MEDECO cruise (RV *Pourquoi Pas?*) in November 2007 with ROV *Victor 6000* (IFREMER, Toulon, France). All metadata are stored in the PANGAEA database (http://www.pangaea.de) and PANGAEA event labels for the experiments are cited accordingly.

The first experiment (Fig. 2a) was using three colonization devices, named CHEMECOLIs (CHEMOsynthetic Ecosystem COlonization of Larval Invertebrates), filled separately with three different substrates (wood—Douglas fir cubes, alfalfa grass and carbonate cubes), in order to mimic reducing habitats (Gaudron et al. 2010). CHEMECOLIs were deployed at 32° 31′97″N, 30°21′18″E, a few decimetres from outcropping authigenic carbonate crusts (CHEMECOLI alfalfa: M70/2b_833_TRAC-11, CHEMECOLI wood: M70/2b_833_TRAC-13). *Glycera noelae* sp. nov. specimens were recovered from two CHEMECOLIs filled with alfalfa (MEDECO-338-S-TRAC126-11) or wood substrates (MEDECO-338-S-TRAC126-13), and the samples were fixed in 95% ethanol and 4% buffered formaldehyde in twice-filtered seawater (TFSW).

The second experiment (Fig. 2b), DIWOOD experiment—wood#5, consisted of a large Douglas fir deployment that comprised one large wood log (length: 200 cm, diameter: 30 cm) with ten smaller logs (length: 25–30 cm, diameter: 10–15 cm) tied to it. This colonization experiment was deployed on sediment (32°32′05″N, 30°21′23″E) close to the CHEMECOLI experiments (M70/2b_846_WOOD-1). Three of the small logs were recovered during the MEDECO cruise in November 2007 (MEDECO2-D339-BOX-4, MEDECO2-D339-BOX-5, MEDECO2-D339-BOX-6). The wood pieces were strongly degraded after 1 year of submersion, mainly due to the activity of wood-boring bivalves of the genus *Xylophaga*. Other colonizing macrofauna included *Glycera noelae* sp. nov. specimens, undetermined species of amphinomids, sipunculids and at least three groups of small crustaceans. Echinids were observed on the wood experiments and on the surrounding seafloor. Samples were examined in a cold room at an in situ temperature of 13°C and the recovered specimens were directly fixed in 99% ethanol or in 4% formaldehyde and later preserved in 70% ethanol.

Observations, measurements and figures of the specimens were made using a Leica Wild M3 stereo microscope, a Zeiss compound microscope, and a Leitz Laborlux S compound microscope, all equipped with a camera lucida.

For SEM investigation parts of the proboscis were dehydrated in a graded ethanol series, critical-point dried using CO_2, mounted on aluminium stubs, coated with gold, and examined with a Zeiss DSM 962.

Abbreviations used in the "Material examined" section include: *cs* complete specimen and *af* anterior fragment. This is followed by: length of specimen (in mm), number of

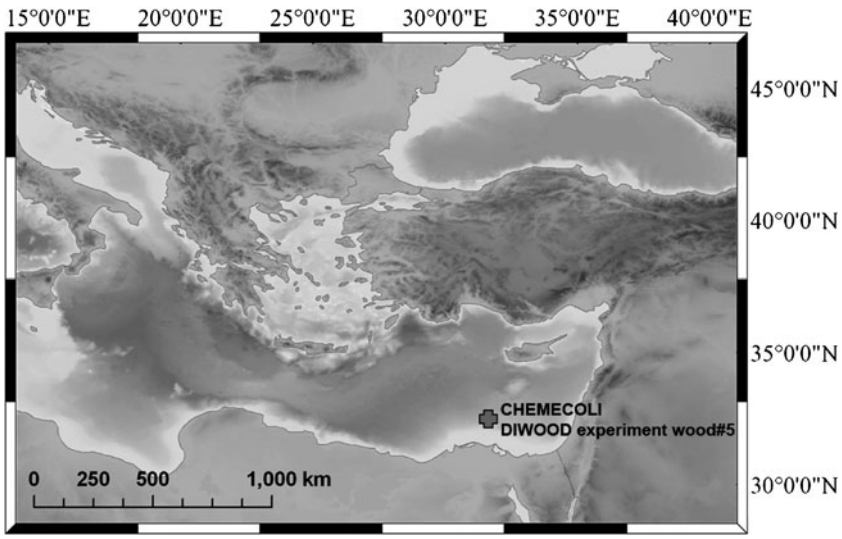

Fig. 1 Location of the CHEMECOLI and DIWOOD experiment—wood#5. The map was generated in ArcMap (ArcGIS Desktop 9.3) with continental margins provided by ESRI (Kranzberg, Germany) and bathymetry obtained from the 2-min Gridded Global Relief Data ETOPO2v2 (2006, http://www.ngdc.noaa.gov/mgg/fliers/06mgg01.html)

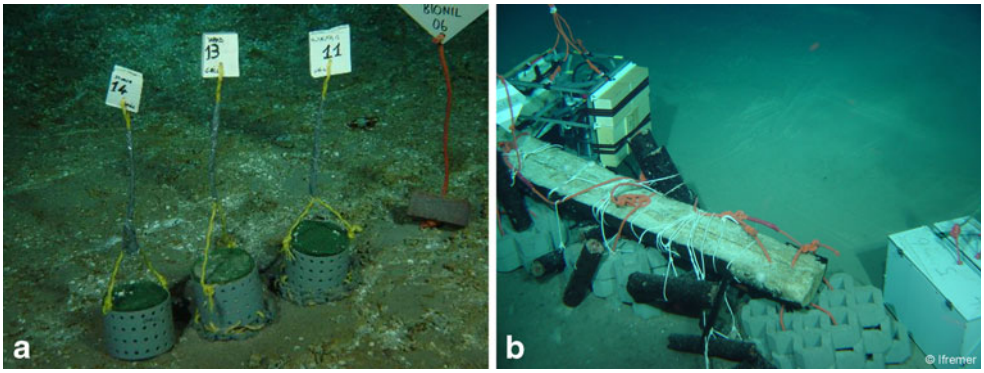

Fig. 2 Pictures taken in situ by ROV *Victor 6000* (IFREMER, Toulon, France) during the recovery of two colonization experiments based on organic substrates at the Nile Deep-Sea Fan, Central site 2A in the eastern Mediterranean Sea: (**a**) CHEMECOLI experiment; (**b**) DIWOOD experiment—wood#5

parapodia, maximum width of specimen including and excluding parapodia (in mm).

The following abbreviations are used for institutions: *MNHN* Muséum national d'Histoire naturelle, Paris and *ZMH* Zoologisches Museum, Hamburg.

Genomic DNA was extracted from ethanol preserved material (Table 1) using the DNeasy blood and tissue kit (Qiagen). Amplification and sequencing of the genes [nuclear ribosomal subunit 18S rDNA, mitochondrial 16S rDNA, mitochondrial cytochrome *c* oxidase subunit I (COI), and the internal transcribed spacers (ITS1 and 2) of the nuclear rDNA] were done with the primers listed in Table 2.

HotStart-PCR was performed in 25-µl reaction volumes including 2.5 µl 10× PCR buffer (BioTherm) with 15 mM $MgCl_2$, 0.5 µl 50 mM $MgCl_2$, 0.5 µl 0.1 M dNTPs, 0.5 µl of each primer (10 pmol/µl), 15.5 µl ddH_2O, 3 µl DNA template, and 2 µl Taq polymerase solution (GeneCraft, 5 U/µl). Biometra Personal Cycler protocol: pre-run: 5 min at 94°C; application of polymerase; 1 cycle: 1 min at 94°C; 40 cycles: 1 min at 94°C, 1 min at 45-53°C, 2 min at 72°C; 1 cycle: 7 min at 72°C. PCR products were verified on a 1% agarose gel and purified with the QIAquick PCR Purification Kit (Qiagen). Sequencing was performed with an ABI PRISM BigDye Terminator Cycle Sequencing Ready Reaction Kit in an ABI PRISM 377 DNA Sequencer (both PE Biosystems). Sequences were assembled and edited using Chromas 1.5 (Technelysium, Tewantin, Australia), whereas the alignment was done with GeneDoc 2.6.002 (Nicholas and Nicholas 1997).

Systematics

Glyceridae Grube, 1850

Key to species of *Glycera* Lamarck, 1818 from the Mediterranean Sea

1. One postchaetal lobe on all parapodia; branchiae absent.....2
– Two postchaetal lobes at least on parapodia of mid-body; branchiae present or absent.....4
2. In mid-body notopodial prechaetal lobes shorter than neuropodial lobes.....3
– In mid-body prechaetal lobes of about same length; main type of proboscidial papillae conical with about 5–20 transverse ridges on one side; ailerons with slightly arched bases.....*Glycera oxycephala* Ehlers, 1887
3. Main type of proboscidial papillae digitiform with an undulating ridge on one side; ailerons with slight dent in pointed triangular bases.....*Glycera lapidum* Quatrefages, 1866
– Main type of proboscidial papillae digitiform with about 7–15 transverse ridges on one side; ailerons with triangular bases.....*Glycera noelae* sp. nov.
4. Ailerons with interramal plate.....5
– Ailerons with deeply incised bases; main type of proboscidial papillae digitiform with one straight median longitudinal ridge on one side; parapodia of mid-body with two short and rounded postchaetal lobes; branchiae absent...*Glycera tesselata* Grube, 1863

Table 1 List of sequenced molecular markers, with accession codes to GenBank

Taxon	Voucher	18S rDNA	16S rDNA	COI	ITS1	ITS2
Glycera noelae sp. nov.	MNHN Type 1521	-	HQ905554	HQ905556	-	HQ905558
	ZMH P25913	HQ905553	HQ905555	HQ905557	HQ905559	HQ905559

Table 2 Primers used for amplification and sequencing

Target	Primer	Sequences (5'→3')	Position	Direction	Reference
18S rDNA	18F35	TCT-CAA-AGA-TTA-AGC-CAT-GCA	35-55	Forward	Struck et al. 2002
	18F509	CCC-CGT-AAT-TGG-AAT-GAG-TAC-A	548-569	Forward	Struck et al. 2002
	18F997	TTC-GAA-GAC-GAT-CAG-ATA-CCG	1044-1065	Forward	Struck et al. 2002
	18R925	GAT-CCA-AGA-ATT-TCA-CCT-CT	955-974	Reverse	Struck et al. 2002
	18R1256	AGC-TCT-CAA-TCT-GTC-AAT-CCT	1236-1256	Reverse	Struck et al. 2002
	18R1779	TGT-TAC-GAC-TTT-TAC-TTC-CTC-TA	1811-1834	Reverse	Struck et al. 2002
16S rDNA	16SArL	CGC-CTG-TTT-ATC-AAA-AAC-AT	571-588	Forward	Palumbi et al. 1991
	16SBrH	CCG-GTC-TGA-ACT-CAG-ATC-ACG-T	1055-1076	Reverse	Palumbi et al. 1991
COI	COI 3	GTN-TGR-GCN-CAY-CAY-ATR-TTY-ACN-GT	850-875	Forward	Kojima et al. 1997
	COI 6 W	GCR-TCN-GGR-TAR-TCN-GAR-TAY-CGY-CGN-GGY-AT	999-1030	Reverse	Jördens et al. 2004
ITS1	18Sf	GGA-AGT-AAA-AGT-CGT-AAC-AAG	-	Forward	Haß-Cordes unpub.
	5.8Sr	GCT-GCG-CTC-TTC-ATC-GAC	-	Reverse	Haß-Cordes unpub.
ITS2	5.8Sv2	ACT-CTA-AGC-GGT-GGA-TCA	-	Forward	Böggemann 2009
	28SR	AAT-GCT-TAA-ATT-CAG-CGG-GTA	-	Reverse	Westheide et al. 2003

5. Main type of proboscidial papillae with terminal fingernail structure on one side.....6
– Main type of proboscidial papillae without terminal fingernail structure on one side.....7
6. Main type of proboscidial papillae with long stalk; ailerons with pointed triangular bases; parapodia of mid-body with slender triangular notopodial and shorter, more or less rounded neuropodial postchaetal lobes; simple, digitiform branchiae, situated termino-dorsally on parapodia.....*Glycera alba* (O.F. Müller, 1776)
– Main type of proboscidial papillae with short stalk; ailerons with triangular bases; parapodia of mid-body with slender triangular notopodial and shorter, more or less rounded neuropodial postchaetal lobes; simple, digitiform branchiae, situated termino-dorsally on parapodia.....*Glycera tridactyla* Schmarda, 1861
7. Main type of proboscidial papillae conical with three ridges on one side.....8
– Main type of proboscidial papillae conical with about 6–16 ridges on one side; ailerons with rounded triangular bases; parapodia of mid-body with two more or less blunt triangular postchaetal lobes; branchiae absent.....*Glycera celtica* O'Connor, 1987
8. Parapodia of mid-body with rounded, sometimes slightly blunt triangular notopodial and slightly shorter, rounded neuropodial postchaetal lobes; simple, retractile, blister-like branchiae, situated medially on anterior side of parapodia; ailerons with triangular bases.....*Glycera fallax* Quatrefages, 1850
– Parapodia of mid-body with two slender triangular postchaetal lobes of about same length; 1–2 retractile, digitiform branchial rami, situated medially on anterior side of parapodia; ailerons with triangular bases.....*Glycera unicornis* Lamarck, 1818

Glycera noelae sp. nov. (Figs. 3, 4)

Material examined

Type material: R/V *Pourquoi Pas?* MEDECO cruise, CHEMECOLI experiment, 32°31′97″N, 30°21′18″E, Nov. 2007, 1,694 m, substrate: wood (MEDECO-338-S-TRAC126-13); holotype: cs/29/94/3.5/2.5 (MNHN Type 1521, two parapodia for DNA)—substrate: alfalfa grass (MEDECO-338-S-TRAC126-11); paratypes: cs/33/83/3.2/2.2, cs/24/84/2.9/2.0 (MNHN Type 1522, two parapodia of each specimen for DNA)—part of proboscis (MNHN Type 1522, on SEM stub)—substrate: wood (MEDECO-338-S-TRAC126-13); paratype: cs/22.8/90/3.2/2.2 (MNHN Type 1523) - paratype: af/20/90/4.2/3.0 (MNHN Type 1523)—R/V *Pourquoi Pas?* MEDECO cruise, DIWOOD experiment—wood#5, 32°32′05″N, 30°21′23″E, Nov. 2007, 1,694 m, substrate: wood (MEDECO2-D339-BOX-4, MEDECO2-D339-BOX-5, MEDECO2-D339-BOX-6); paratypes: cs/47/95/3.5/2.0, cs/40/85/3.5/2.0 (ZMH P25913, one parapodium for DNA)—paratypes: cs/43/92/3.0/1.7, af/29/57/3.0/1.7 (ZMH P25914, one parapodium for DNA)—part of proboscis (ZMH P25914a, on SEM stub)—paratype: cs/26/48/4.0/2.7 (ZMH P25615)—paratypes: cs/47/94/3.0/1.7, af/14/31/2.8/1.6 (ZMH P25916)

Diagnosis Proboscidial papillae mainly digitiform with about 7–15 ridges; ailerons with triangular bases; parapodia

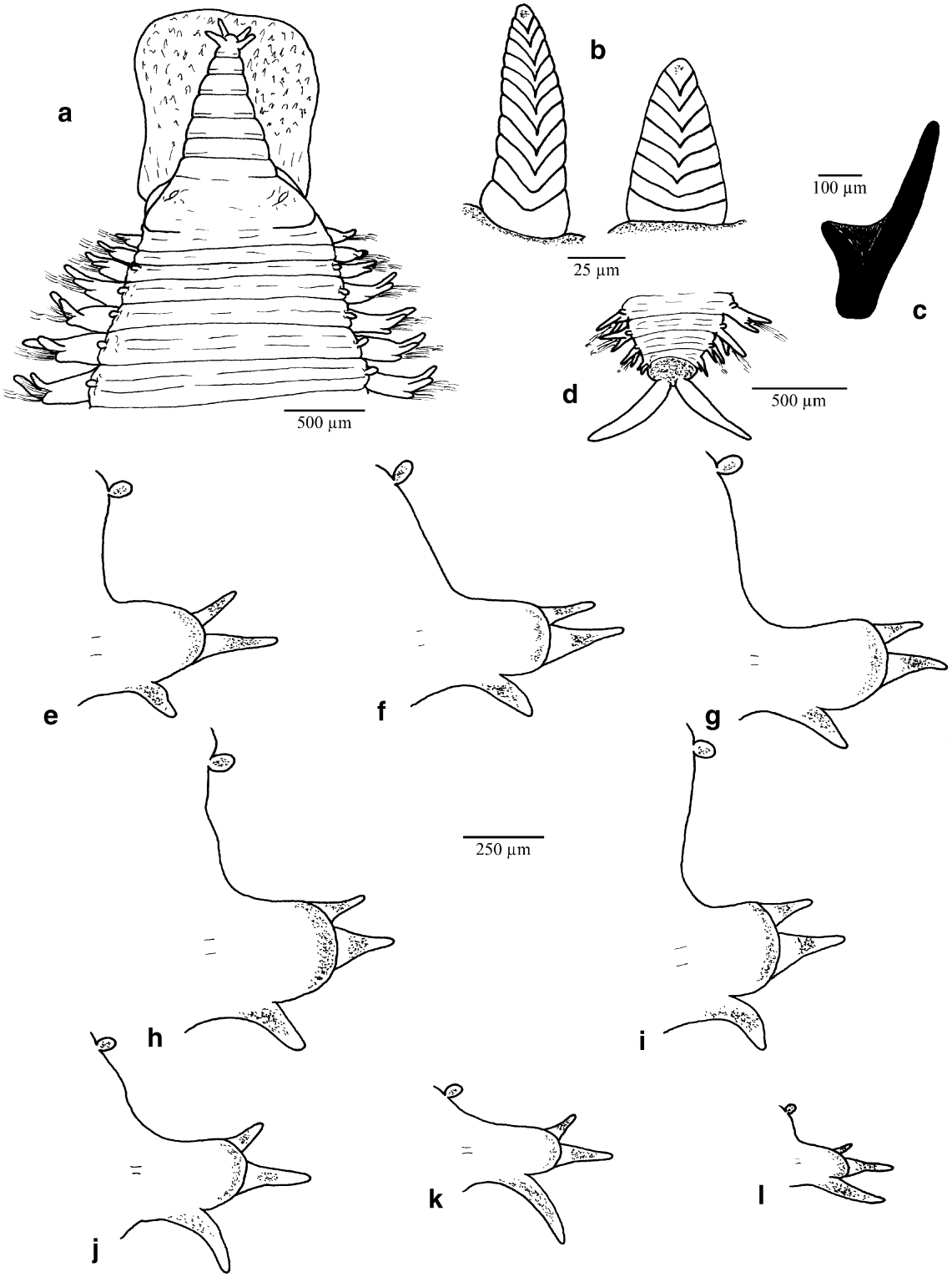

Fig. 3 *Glycera noelae* sp. nov. (**a**) Anterior end with partly everted proboscis; dorsal view. (**b**) Proboscidial papillae; posterior view. (**c**) Aileron. (**d**) Posterior end; dorsal view. (**e**–**l**) Anterior to posterior parapodia; posterior view, chaetae omitted (**a**, **c**–**l**: MNHN Type 1521; **b**: ZMH P25913)

of mid-body with slightly longer neuropodial than notopodial prechaetal lobes and one rounded postchaetal lobe; branchiae absent.

Description Body up to 47 mm long with up to 95 segments; tapering at both ends. Anterior segments biannulate, from about 6–8 chaetigers more or less distinctly

triannulate (Fig. 3a); two anterior annuli of about same length, posterior annulus slightly longer. Preserved specimens yellowish, with numerous diffusely distributed small brown pigmented spots, denser on anterior and posterior parts of body, especially on parapodial lobes, dorsal and ventral cirri, pygidium and anal cirri.

Conical prostomium consisting of about eight rings; terminal ring with four appendages, anterior pair situated termino-laterally and posterior pair more dorso-laterally; basal ring with one pair of nuchal organs; eyes absent (Fig. 3a).

Proboscis long, cylindrical to club-shaped, muscular, densely covered with two types of papillae with subapical tufts of cilia, arranged in more or less distinct longitudinal rows: (1) numerous digitiform papillae with about 7–15 ridges on posterior surface (Figs. 3b and 4a, c); (2) isolated, slightly shorter and broader, conical to oval papillae with about 5–10 ridges (Figs. 3b and 4a, d); ridges U-shaped basally and V-shaped apically; anterior surface of papillae without ridges (Fig. 4b). Terminal part of proboscis with four dark hook-shaped jaws arranged in a cross and accessory ailerons with triangular base (Fig. 3c).

First two pairs of parapodia uniramous, consisting of neuropodia, ventral cirri and compound chaetae only; following parapodia biramous (Fig. 3e–l). Two slender triangular to digitiform prechaetal lobes; neuropodial lobe always slightly longer than notopodial lobe; both lobes becoming slightly slimmer in posterior parapodia; in last parapodia notopodial lobe much shorter than neuropodial one. One shorter, rounded postchaetal lobe. Dorsal cirri indistinctly from 2nd or more clearly from 3rd parapodium, oval to globular; inserted—most clearly in anterior part of body—on body wall far above parapodial base. Ventral cirri slender triangular to digitiform, shorter than postchaetal lobes; in posterior parapodia, slender and elongated; in last parapodia, about as long as neuropodial prechaetal lobe; situated medio-ventrally on parapodia, subterminally on posterior segments. Branchiae absent.

Notopodia and neuropodia each with a single acicula. Chaetae typical of the genus: notochaetae slender, straight or weakly recurved capillary with one side covered with spines or hairs. Neurochaetae compound spinigers with blades of different lengths, covered on one side with spines or hairs.

Pygidium with a dorsal anus and a terminal pair of slender, elongated cirri (Fig. 3d).

DNA remarks Only two of the specimens of *Glycera noelae* sp. nov. were successfully sequenced (Table 1). However, the more conservative coding regions from the mitochondrial ribosomal subunit 16S rDNA and the mitochondrial cytochrome *c* oxidase subunit I gene (COI), as well as the more variable non-coding internal transcribed spacer of the nuclear rDNA (ITS2) were identical, which

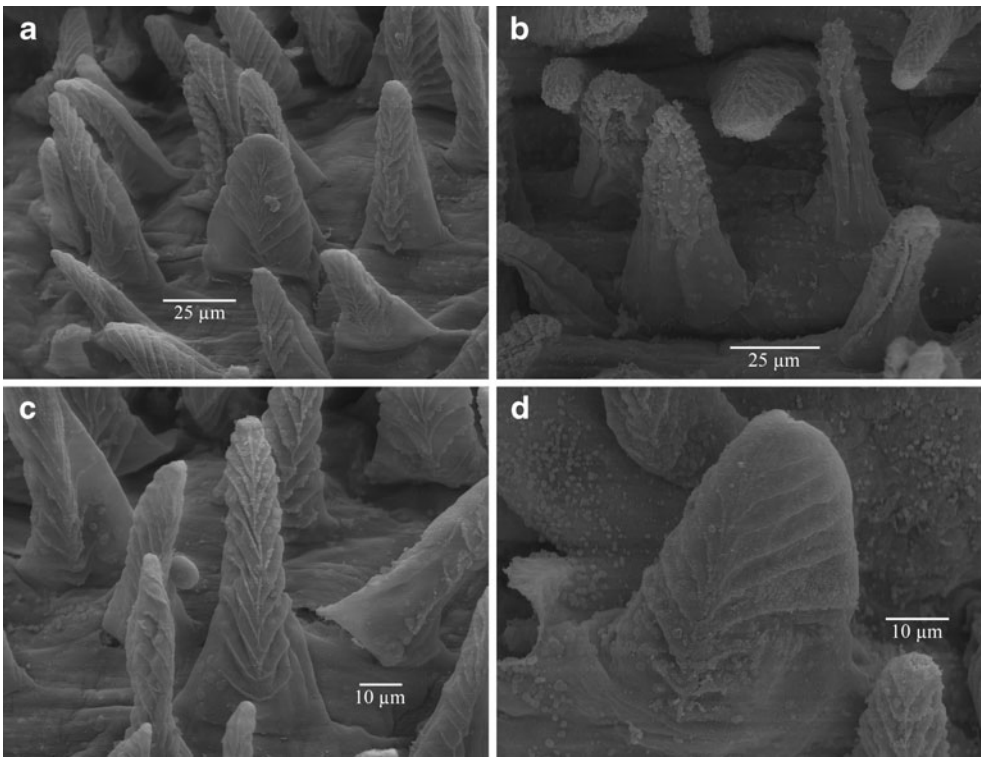

Fig. 4 *Glycera noelae* sp. nov. (**a**) Proboscidial papillae; posterior view. (**b**) Main type of proboscidial papillae; posterior view. (**c**) Additional type of proboscidial papillae; posterior view. (**d**) Proboscidial papillae; anterior view (**a**–**d**: ZMH P25914a)

demonstrated that there was no restriction in gene flow between the populations of the two investigated areas.

Distribution Eastern Mediterranean Sea, near cold seeps; 1,694 m depth.

Etymology The species is named in memory of Andrea Noël (1966–2010), the much too early deceased former secretary of the Zoology Department at the University in Osnabrück.

Remarks Glycera noelae sp. nov. shares great similarities with *Glycera capitata* Ørsted, 1842 and *Glycera lapidum* Quatrefages, 1866. However, the proboscidial papillae of the latter two taxa are provided either with only one straight median longitudinal ridge or with an undulating ridge instead of numerous transversal ones, which are also known from *Glycera* species like: *Glycera oxycephala* Ehlers, 1887, *Glycera brevicirris* Grube, 1870, *Glycera russa* Grube, 1870 or *Glycera bassensis* Böggemann and Fiege, 2001.

Discussion

The CHEMECOLI and DIWOOD experiment—wood#5 are part of the projects CHEMECO (ESF EURODEEP) and GDRE DIWOOD (CNRS-MPG). The experiments mainly focus on the settlement success of typical vent/seep organisms and their associated microorganisms on organic substrates (Gaudron et al. 2010). However, also opportunistic species, like glycerids, were found in these habitats (Böggemann 2002, 2006b; Desbruyères 2006), and they were never before reported from interstitial wooden spaces created by wood-boring bivalves.

Unlike DIWOOD experiment—wood#5, for the CHEMECOLI experiment Glyceridae were the only top predator as they are seen as carnivorous polychaetes (Pleijel 2001). Glycerid polychaete, e.g. *Glycera dibranchiata* from mudflats has been shown to be highly tolerant to sulphide exposure (e.g. Hance et al. 2008; Ortega et al. 2008) and this may as well explain why this new species of *Glycera* was attracted to both colonization experiments in the eastern Mediterranean based on organic substrates that has been shown to produce sulphide (Gaudron et al. 2010) due to microbiological process of degradation by sulphate-reducing bacteria (SRB) as seen in whale carcasses (Treude et al. 2009).

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