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Taxonomic Study on the Oenonid and Onuphid Polychaetes (Polychaeta: Eunicida: Oenonidae, Onuphidae) from Korea

조선대학교 대학원

글로벌바이오융합학과

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한국산 홍점갯지렁이과 및 집갯지렁이과
다모류(다모강: 털갯지렁이목)의 분류학적 연구

2024 년 2 월 23 일

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지도교수 윤 성 명

이 논문을 이학석사학위신청 논문으로 제출함

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글로벌바이오융합학과

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강성훈의 석사학위논문을 인준함

위원장　　이 정 섭　　(인)

위 원　　송 상 기　　(인)

위 원　　윤 성 명　　(인)

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조선대학교 대학원

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지도교수 윤 성 명

글로벌바이오융합학과

조선대학교 대학원

홍점갯지렁이류(oenonids)와 집갯지렁이류(onuohids)는 해양 저서무척추동물 군집에서 흔히 발견되는 갯지렁이의 한 종류로, 생태계에서 포식자 및 피식자로서 중요한 역할을 하는 것으로 알려져 있다. 한국 해역에서 보고된 홍점갯지렁이류는 2 속 2 종, 집갯지렁이류는 4 속 5 종이며, 그 가운데 특히 홍점갯지렁이(*Arabella iricolor* (Montagu, 1804))와 털보집갯지렁이(*Diopatra sugokai* Izuka, 1907)는 형태학적인 연구가 잘 진행되어 있지 않았기에 본 연구에서는 비교형태학적 연구를 통해 이들의 기록을 재검토하고 이들과 관련된 분류군에 대하여 정확한 종의 식별 및 새로운 종의 발굴을 목표로 하였다. 2021 년 4 월부터 2023 년 8 월 사이에 채집된 표본들과 조선대학교 생명과학과에 보관되어 있던 표본들을 포함하여, 한국의 28 개 지역에서 채집된 홍점갯지렁이류와 집갯지렁이류 표본들에 대한 분류학적 연구를

수행한 결과는 다음과 같다: (1) 2 종의 신종, 또는 신종후보종을 확인함(*Arabella* n. sp., *Diopatra* n. sp.), (2) 1 종의 한국 미기록종을 확인함(*Oenone fulgida* (Lamarck, 1818)). *Arabella* n. sp.의 경우 위턱(maxillae) carriers 의 배쪽이 등쪽보다 길거나 비슷하고, 첫 번째 위턱은 양쪽 모두 낫 모양이며, 최복측 강모가 guard 부위로 가면서 점진적으로 가늘어지고, 항문마디(pygidium)가 부푼 pads 형태인 특징들을 가지고 있다. 이런 특징들로 이 종은 홍점갯지렁이를 비롯한 *Arabella* 속의 다른 종들과 구별된다. *Diopatra* n. sp.의 경우 아래턱(mandibles)의 말단에 2 개의 홈을 가지며, 아래턱 carriers 의 안쪽에 밝은 긴 선이 나타나고, 빗 모양 강모(pectinate chaetae)의 이 개수가 24-30 개로 일정하게 나타난다. 이런 특징들로 이 종은 털보집갯지렁이를 포함한 *Diopatra* 속의 다른 종들과 구별된다. 홍점갯지렁이류의 일종인 *Oenone fulgida* 는 한국 미기록종으로서 입앞마디 배쪽에 눈이 없고, 1 번 위턱이 대칭인 것이 이 속의 다른 종과 구별되는 종의 특징이다. 본 논문에서는 3 종에 대하여 자세한 기재와 도판을 작성하였으며, 종들에 대한 검색표를 작성하였고, 근연종들과 비교하여 논의하였다.

주요어: 한국, 홍점갯지렁이과, 집갯지렁이과, 신종, 형태학적 분석, 분류학

I. INTRODUCTION

The family Oenonidae Kinberg, 1865 belongs to Eunicida Dales, 1962 is characterized by having a maxillary apparatus of prionognath type. Prionognath type is characterized by the presence of a pair of dorsal and unpaired ventral maxillary carriers that are much longer than the maxillae. Currently, Oenonidae comprises 14 genera and 89 species (Orensanz, 1990; Zanol *et al*., 2021; WoRMS, 2023). This study focused on two oenonid genera, *Arabella* Grube, 1850 and *Oenone* Lamarck, 1818, in Korea. Studies of the oenonids in Korean fauna were mainly carried out by Paik (Paik, 1989; Paik, 1997). After this, taxonomic studies of oenonids had not yet been performed.

The genus *Arabella* Grube, 1850 is characterized by the absence of antennae, the presence of eyes, and chaetigers with only capillary chaetae (Colbath, 1989; Steiner and Amaral, 2009; Zanol and Ruta, 2015; Ribeiro *et al*., 2018; Zanol *et al*., 2021). The members of the genus are free–living or parasitic during a life cycle and are found in the intertidal and subtidal zones including sandy or muddy bottoms (Hernández-Alcántara and Solís-Weiss, 1998; Zanol *et al*., 2021). Currently, 25 species of *Arabella* have been reported worldwide as valid species (WoRMS, 2023). Among them, only one species, *Arabella iricolor* (Montagu, 1804), has been recorded from Korea (Paik, 1989). *Arabella iricolor*, the type species of the genus, had long been known as a cosmopolitan species (Colbath, 1989) due to high morphological similarity between *Arabella* species. Therefore, most materials of *Arabella* were previously confused and misidentified as *A. iricolor* (Colbath, 1989). Colbath (1989) points out that *Arabella* species can be identified based on jaw structure, ventralmost chaeta, and pygidium. However, those were overlooked in most previous studies on *A. iricolor* from UK (Montagu, 1804), India (Treadwell, 1921), Japan (Imajima and Hartman, 1964), Mexico (Fauchald, 1970), Kuwait (Mohammad,1981), Korea (Paik, 1989), Australia (Mustaquim, 2000), and Pakistan (Mustaquim, 2000). Therefore, *A. iricolor* is presently recognized as a species complex (Colbath, 1989; Steiner and Amaral, 2009; Zanol and Ruta, 2015).

The genus *Oenone* Lamarck, 1818 is characterized by the three antennae, two pairs of eyes, subacicular hooded hook, and presence of dorsal cirri (Crossland, 1924; Day, 1967; Zanol and Ruta, 2015; Zanol *et al*., 2021). The members of the genus are free–living and are found in the subtidal zone including coral rubble, underneath stones, and coral (Zanol and Ruta, 2015; Zanol *et al*., 2021). Currently, 2 species of *Oenone* have been reported worldwide as valid species (WoRMS, 2023). This genus has not yet been recorded in Korean fauna.

The family Onuphidae Kinberg, 1865 belongs to Eunicida Dales, 1962 is characterized by the presence of well-delimited dorsal frontal lips and maxillary apparatus of labidognath type. Labidognath type is characterized by the presence of a pair of dorsal maxillary carriers that are much shorter than the maxillae. Currently, Onuphidae comprises 22 genera and 340 species. Among onuphid genera, this study focused on *Diopatra* Audouin and Milne 1833 (Paxton, 1998; Zanol *et al*., 2021; WoRMS, 2023).

The genus *Diopatra* Audouin and Milne 1833 is characterized by the spiraled shape of branchiae (Izuka, 1907; Paxton, 1998; Zanol *et al*., 2021; Hektoen *et al*., 2022). The members of the genus are tubicolous dwellers with spiraled branchiae and are found in the intertidal zones including sandflat (Paxton, 1998; Fauchald *et al*., 2012; Paxton and Arias, 2017; Zanol *et al*., 2021). Currently, 67 species of *Diopatra* have been reported worldwide as valid species (WoRMS, 2023). Among them, only one species, *Diopatra sugokai* Izuka, 1907 has been recorded from Korea (Paik, 1989).

Here, the author describes a new oenonid and a new onuphid species collected from the coastal habitats of Korea. Also, a newly reported oenonid species, collected from the subtidal habitats along the coasts of Jeju-do Island, in Korean fauna is reported. This paper includes the detailed descriptions and illustrations of these three species with the keys to them.

II. MATERIALS AND METHODS

1. Collection and morphological analysis

Samples were collected at 28 localities including intertidal to subtidal zones in South Korea (Fig. 1). Specimens were sorted using sieves with a pore size of 0.5 mm, fixed initially with 5% formaldehyde–seawater solution and transferred to 95% ethyl alcohol. The characteristics of the whole body were observed with appendages dissected in a petri dish using dissection forceps or surgical knives and needles under a stereomicroscope (Olympus, SZH10, Japan). Dissected specimens were mounted onto permanent slides using glycerol. Drawings were made under the stereomicroscope and light microscope (Nikon, eclipse 80i, Japan) with the aid of drawing tubes. Specimens for scanning electron microscopy (SEM) were dehydrated by a tert–butyl alchol freeze dryer (VFD–21S; Vacuum Device, Ibaraki, Japan). They were mounted on stubs and coated with gold–palladium. SEM observations were carried out using a scanning electron microscope (SU3500; Hitachi, Tokyo, Japan). Maxillary plates nomenclature (MxI, MxII, MxIII, MxIV, and MxV) and formula were followed by the traditional classification (Zanol and Ruta, 2015; Paxton, 1998).

2. General morphology

Body shape. Body of oenonids and onuphids is elongated, divided into an anterior region consisting of the prostomium and peristomium (head), a long median region (segmentation), and a posterior region (pygidium).

Head. The prostomium is round and consists of appendages that serve sensory functions (Antennae, palps, eyes). The peristomium surrounds the mouth ventrally, prostomium dorsally, and without parapodia.

Jaw structure. The mandibles consist of cutting plates and carriers. The maxillary structure is composed of maxillae and carriers. Maxillae are five pairs of plates. Mandible carriers and maxillary carriers form a pair.

Parapodia. Parapodia appear in pairs in each chaetigers and are typically composed of the prechaetal lobe, postchaetal lobe, and chaetae. Other appendages include branchiae, dorsal cirri, ventral cirri, and without aciculae.

Chaetae. Chaetae typically consist of limbate capillary chaetae. *Arabella* has serrated chaetae and modified ventralmost chaeta. *Oenone* and *Diopatra* are with Subacicular hooks. In *Diopatra*, pectinate chaetae, pseudocompound hooks, and simple hooks appear.

Pygidium. Pygidial segment takes on forms of cirri and pads.

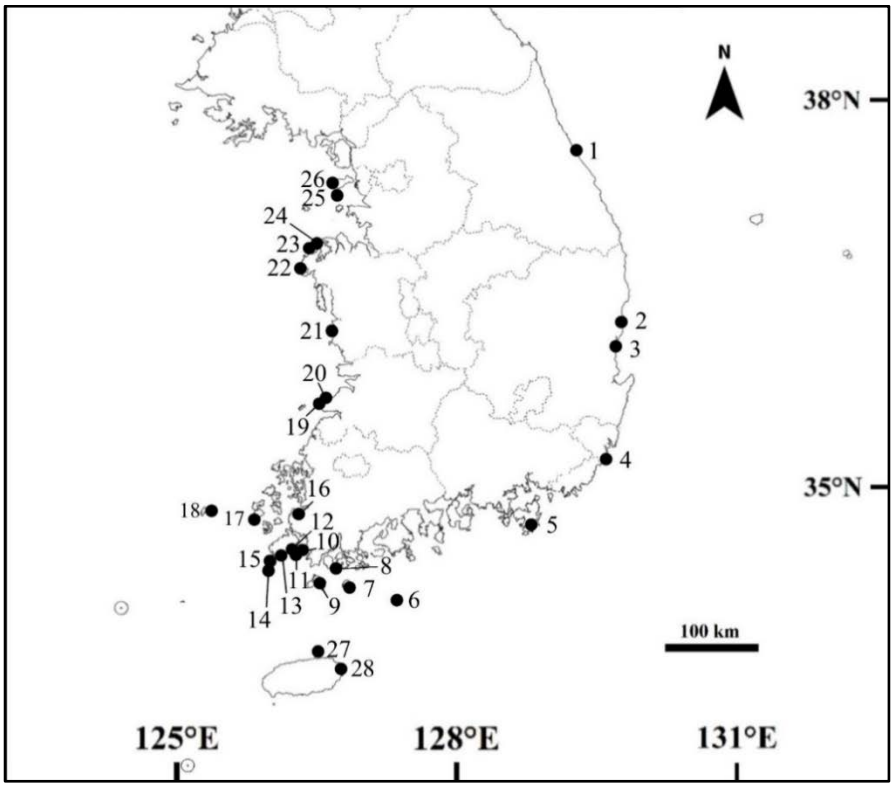

Fig. 1. Localities of the present study: 1, Maebawi–gil, Hyeonnam–myeon, Yangyang–gun; 2, Buheung–ri, Namjeong–myeon, Yeongdeok–gun; 3, Gyeongjeong–ri, Chuksan–myeon, Yeongdeok–gun; 4, Jinha–ri, Seosaeng–myeon, Ulju–gun; 5, Galgot–ri, Nambu–myeon, Geoje–si; 6, Seodo–ri, Samsan–myeon, Yeosu–si; 7, Cheonggye–ri, Cheongsan–myeon, Wando–gun; 8, Jeongdo 1–gil, Wando–eup, Wando–gun; 9, Yesong–ri, Bogil–myeon, Wando–gun; 10, Geumgap–ri, Uisin–myeon, Jindo–gun; 11, Jungnim–ri, Imhoe–myeon, Jindo–gun; 12, Tamnip-gil, Imhoe-myeon, Jindo-gun; 13, Namdong–ri, Imhoe–myeon, Jindo–gun; 14, Gwanmaedo–ri, Jodo–myeon, Jindo–gun; 15, Sinyuk–ri, Jodo–myeon, Jindo–gun; 16, Geumho–ri, Sani–myeon, Haenam–gun; 17, Uido–ri, Docho–myeon, Sinan–gun; 18, Ye–ri, Heuksan–myeon, Sinan–gun; 19, Gyeokpo–ri, Byeonsan–myeon, Buan–gun; 20, Unsan–ri, Byeonsan–myeon, Buan–gun; 21, Doksan–ri, Ungcheon–eup, Boryeong–si; 22, Mohang–ri, Sowon–myeon, Taean–gun; 23, Hagampo–gil, Wonbuk–myeon, Taean–gun; 24, Nae–ri, Iwon–myeon, Taean–gun; 25, Muui–dong, Jung–gu, Incheon; 26, Eurwang–dong, Jung–gu, Incheon; 27, Haengwon-ri, Gujwa-eup, Jeju-si, Jeju-do; 28, Goseong–ri, Seongsan–eup, Seogwipo–si.

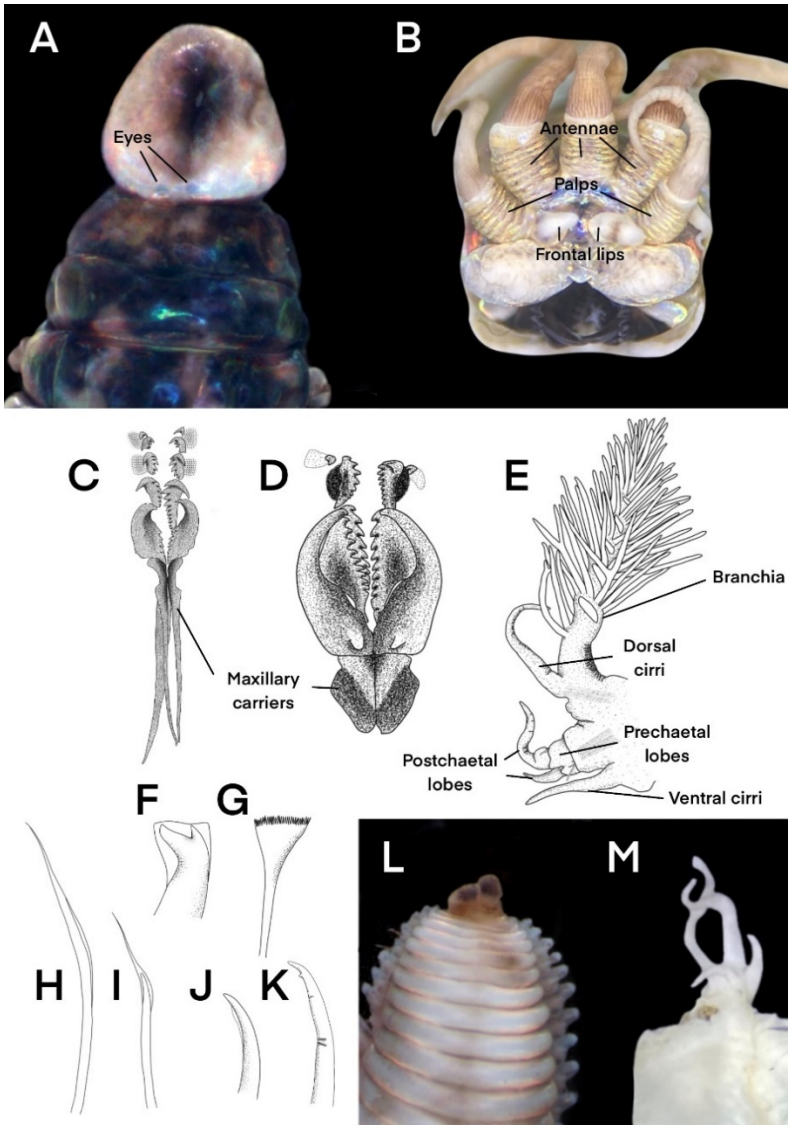

Fig. 2. Morphology of oenonids and onuphids. A, *Arabella* n. sp., anterior of body, dorsal view; B, *Diopatra* n. sp., prostomium, anterior view; C, maxillary apparatus of prionognath type, *Arabella* n. sp.; D, maxillary apparatus of labidognath type. *Diopatra* n. sp.; E, parapodium 5, *Diopatra* n. sp.; F, subacicular hook, *Diopatra* n. sp.; G, pectinate chaeta, *Diopatra* n. sp.; H, limbate capillary chaeta, *Arabella* n. sp.; I, modified ventralmost chaeta, *Arabella* n. sp.; J, simple hook, *Diopatra* n. sp.; K, pseudocompound hook, *Diopatra* n. sp.; L, pad form of pygidium *Arabella* n. sp.; M, cirri form of pygidium, *Diopatra* n. sp.

III. SYSTEMATIC ACCOUNTS

Order Eunicida Dales, 1962 털갯지렁이목

Family Oenonidae Kinberg, 1865 홍점갯지렁이과

Genus *Arabella* Grube, 1850 홍점갯지렁이속

1. *Arabella* n. sp.

Material examined. *Type locality*: Korea. Buheung–ri, Namjeong–myeon, Yeongdeok–gun, Gyeongsangbuk–do (36°17’31.2”N 129°22’41.0”E), 12 November 2022, intertidal mussel colonies. ***Holotype*.** complete ind. ***Paratypes*.** 1 ind. (complete); 1 ind. (incomplete); 1 ind. (complete).

***Non–type materials*.** Korea: 1 ind. (incomplete), Maebawi–gil, Hyeonnam–myeon, Yangyang–gun, Gangwon–do (37°52’42.2”N 128°47’19.3”E), 28 April 2021, intertidal mussel colonies; 6 ind. (1 complete and 5 incomplete ind.), Gyeongjeong–ri, Chuksan–myeon, Yeongdeok–gun, Gyeongsangbuk–do (36°28’43.8”N 129°26’1.4”E), 17 September 2014, intertidal mussel colonies; 1 ind. (incomplete), Jinha–ri, Seosaeng–myeon, Ulju–gun, Ulsan (35°22’26.6”N 129°20’52.2”E), 18 May 2012, intertidal mussel colonies; 2 ind. (complete), Galgot–ri, Nambu–myeon, Geoje–si, Gyeongsangnam–do (34°44’18.9”N 128°39’23.6”E), 18 May 2014, , intertidal mussel colonies; 8 ind. (7 complete and 1 incomplete), Seodo–ri, Samsan–myeon, Yeosu–si, Jeollanam–do (34°03'18.8"N 127°17'36.4"E), 22 October 2022, intertidal mussel colonies; 2 ind. (incomplete), Cheonggye–ri, Cheongsan–myeon, Wando–gun, Jeollanam–do (34°09'20.1"N 126°54'01.0"E), 22 August 2021, intertidal mussel colonies; 1 ind. (incomplete), Jeongdo 1–gil, Wando–eup, Wando–gun, Jeollanam–do (34°17'47.3"N 126°42'05.2"E), 24 August 2021, intertidal mussel colonies; 1 ind. (incomplete), Yesong–ri, Bogil–myeon, Wando–gun, Jeollanam–do (34°08'06.8"N 126°33'40.2"E), 26 May 2021, intertidal mussel colonies; 3 ind. (2

complete and 1 incomplete), Geumgap–ri, Uisin–myeon, Jindo–gun, Jeollanam–do (34°23'27.0"N 126°16'52.2"E), 29 April 2022, intertidal mussel colonies; 3 ind. (complete), Jungnim–ri, Imhoe–myeon, Jindo–gun, Jeollanam–do (34°22'43.9"N 126°16'3.3"E), 30 July 2022, intertidal mussel colonies; 3 ind. (complete), Tamnip-gil, Imhoe-myeon, Jindo-gun Jeollanam–do (34°22'40.0"N 126°14'35.9"E), 30 July 2022, intertidal mussel colonies; 2 ind. (incomplete), Namdong–ri, Imhoe–myeon, Jindo–gun, Jeollanam–do (34°21'58.5"N 126°09'13.1"E), 17 June 2022, intertidal mussel colonies; 5 ind. (complete), Gwanmaedo–ri, Jodo–myeon, Jindo–gun, Jeollanam–do (34°14'16.1"N 126°03'37.4"E), 14 June 2022, intertidal mussel colonies; 3 ind.(complete), Sinyuk–ri, Jodo–myeon, Jindo–gun, Jeollanam–do (34°16'53.4"N 126°04'53.1"E), 15 June 2022, intertidal mussel colonies; 2 ind. (incomplete), Uido–ri, Docho–myeon, Sinan–gun, Jeollanam–do (34°36'39.0"N 125°49'32.6"E), 31 May 2022, intertidal mussel colonies; 6 ind. (complete), Ye–ri, Heuksan–myeon, Sinan–gun, Jeollanam–do (34°39'39.2"N 125°25'23.1"E), 25 August 2022, intertidal mussel colonies; 3 ind. (complete), Nae–ri, Iwon–myeon, Taean–gun, Chungcheongnam–do (36°56’2.1”N 126°17’31.5”E), 24 February 2016, intertidal oyster colonies; 1 ind.(complete), Muui–dong, Jung–gu, Incheon (37°22’20.6”N 126°26’24.6”E), 21 April 2023, intertidal oyster colonies ; 2 ind. (1 complete and 1 incomplete), Eurwang–dong, Jung–gu, Incheon (37°26’7.5”N 126°22’48.8”E), 21 April 2023, intertidal oyster colonies; 3 ind. (2 complete and 1 incomplete), Goseong–ri, Seongsan–eup, Seogwipo–si, Jeju–do (33°25'23.7"N 126°55'45.6"E), 14 July 2022, intertidal seaweed bottom.

Diagnosis. Prostomium tapering anteriorly with four eyes on posterior margin of prostomium. Peristomium forming double rings. Maxillary carriers long and slender, and ventral carriers longer than dorsal. MxI falcate, asymmetric; left MxI robust and right gracile; right MxII long; MxV both with one tooth. Prechaetal lobe shorter than postchaetal, each rounded and digitiform; posteior postchaetal lobe shorter than chaetae. Most chaetae limbate capillary, finely or coarsely serrated; modified ventralmost chaeta tapering gradually to guard. Pygidium with two swollen pads.

Description. Holotype, 426.0 mm long, 4.0 mm wide, and with 559 chaetigers. Paratypes, smallest complete specimen, 127.0 mm long, 1.8 mm wide, and with 298 chaetigers; largest complete specimen, 480.0 mm long, 3.7 mm wide, and with 523 chaetigers.

Body slender and long, widest at anterior chaetigers, after that having similar width, and abruptly tapering at posterior chaetigers and pygidium. Body color brown overall, sometimes discolorated during fixation; dorsal blue long bands appeared from anterior to posterior segments (Figs. 4A and 4B).

Prostomium conical, inflated; dorsal area with median groove from anterior to posterior margins; ventral area wider, with median groove; sometimes dorsal groove absent. Eyes two pairs, arranged in a line at base of dorsal prostomium, sometimes discolored; median eyes smaller than lateral. Antenna absent. Peristomium double ringed; rings wider than prostomium, equal or shorter than next chaetigers (Fig. 5A).

Mandibles black colored, connected by short ligaments; cutting plate ligament at distal margin, rounded, and shorter than mandibular carriers (Fig. 5C). Dorsal maxillary carriers paired, but ventral carrier unpaired; ventral maxillary carrier longer than or equal to dorsal, widest at anterior region and tapering toward posterior (Fig. 5D). MxI asymmetrical, left gracile and right robust, distal shape both falcate, MxII, right longer than left, MxII and MxIII with additional anterior teeth, MxIII and MxIV with broad chitinous plates, maxillary formula of one paratype: MxI = (1, 11) + (1, 12); MxII = 7 + 14; MxIII = 6+7; MxIV = 6+8; MxV = 1+1 (Fig. 5D).

Parapodia smallest in anteriormost and posteriormost parts; size increased from anterior to median, decreased from median to posterior parts, and similar in size in median part (Figs. 6A and 6B). Dorsal cirri absent. Prechaetal lobe always rounded, shorter than postchaetal lobe. Postchaetal lobe conical or digitiform, more than twice as long as prechaetal lobe, and shorter than chaetae (Figs. 6A and 6B). All chaetae capillary shaped; superior chaeta longer than others; superior and mediodorsal chaetae finely or coarsely serrated, medioventral chaetae coarsely

serrated; modified ventralmost chaeta tapering gradually to guard (Figs. 4A and 4B; Figs. 6D to 6G).

Pygidium consisting of 2–3 last chaetigers, with pair of swollen pads as long as pygidium, lacking cirri (Fig. 4B; Fig. 5B).

Remark. In *Arabella* species, *Arabella* n. sp. and *A. iricolor*, known as cosmopolitan species, have similar characteristics such as modified ventralmost chaeta gradually tapering, posterior postchaetal lobe shorter than chaetae, right MxII long, MxV both with one tooth. In this respect, *Arabella* materials have been treated as *A. iricolor* only in Korean fauna (Paik, 1989). However, our *Arabella* materials of the present study can be distinguished from *A. iricolor* by the following features: 1) MxI distal shape is both falcate (*vs*. left is falcate and right is bifid in *A. iricolor*); 2) pygidium shape is swollen pads and lacking cirri (*vs*. not swollen pads, with cirri only in *A. iricolor*); 3) ventral maxillary carrier longer than or equal to dorsal carriers (*vs*. shorter than dorsal carriers in *A. iricolor*) (Table 1; Fauchal, 1970; Colbath, 1989; Blake, 1995; Bogantes, 2014; Zanol and Ruta, 2015). Among 25 known *Arabella* species, there are eight species with modified ventralmost chaeta gradually tapering to guard as like as *Arabella* n. sp.: *A. iricolor*, *A. semimaculata* (Mooro, 1911), *A. logani* Crossland, 1924, *A. pectinata* Fauchald, 1970, *A. longicirrata* Hartmann–Schröder, 1979, *A. protomutans* Orensanz, 1990, *A. aracaensis* Steiner and Amaral, 2009, and *A. (Arabella) pulvinata* Zanol and Ruta, 2015. Among them, *A. longicirrata* and *A. semimaculata* are differentiated from other species by having long dorsal cirri (Monro, 1931; Crossland, 1924; Fauchal, 1970; Hartmann–Schröder, 1979; Colbath, 1989; Orensanz, 1990; Blake, 1995; Steiner and Amaral, 2009; Bogantes, 2014; Zanol and Ruta, 2015). In addition to this, *Arabella* n. sp. is also similar to *A. aracaensis* in having MxI both falcate in distal shape. However, the new species can be distinguished from the latter by the following characteristics: 1) pygidium is of swollen pad shape (*vs*. not swollen pad shape, with cirri only in the latter); 2) ventral maxillary carrier longer than or equal to dorsal (*vs*. shorter than dorsal carriers in the latter) (Table 1; Steiner and Amaral, 2009).

Habitat. Intertidal seaweed bed, mussel and oyster colonies.

Distribution. Korea.

Discussion. In East Asia, the taxonomic works on *Arabella* species have been conducted without description of significant morphological features distinguishing the species such as MxI distal shape, modified ventralmost chaeta, and pygidium (Imajima and Hartman, 1964; Paik, 1989). In this study, we collected *Arabella* samples from 20 localities in South Korea including Yeongdeok, Namae, Geomundo, Wando, Jindo, Seongsanpo, and Incheon, where *A. iricolor* was previously recorded by Paik (1989). The samples were morphologically analyzed, based on the characters of MxI distal shape, modified ventralmost chaeta, and pygidium. As a result, all the specimens collected from those 20 localities were identified as *Arabella* n. sp. in that they have MxI distal shapes of both falcate, modified ventralmost chaeta tapering gradually to guard, and pygidium of swollen pads. In this respect, *Arabella* n. sp. can be remarkably distinguished from *A. iricolor* (Colbath, 1989; Zanol and Ruta, 2015). We expect that *A. iricolor*, originally described from the south coast of Devonshire in English (Montagu, 1804), is unlikely to occur in Korea.

The genus *Arabella* can be divided into two subgroups based on the morphology of modified ventralmost chaeta, tapering gradually to guard or tapering abruptly to guard, and this should be a significant key character of *Arabella* taxonomy (Colbath, 1989; Zanol and Ruta, 2015). In practice, however, this character is so delicate that careful observation is needed to apply. *Arabella* n. sp. and *A. monroi* Colbath, 1989 are very similar in having falcate shape of MxI, long right MxII, MxV teeth formula of 1+1, shorter postchaetal lobes length to chaetae, and pygidium of two swollen pads, but the former differs from the latter by having the modified ventralmost chaeta tapering gradually to guard (*vs*. tapering abruptly to guard in the latter). These two species are also distinguishable from each other in the maxillary carriers length of ventral in relation to dorsal (equal or longer in the former *vs*. shorter in the latter) (Table. 1).

Key to known species of the genus *Arabella* (based on Colbath, 1989; Zanol and Ruta, 2015**)**

1. Posteior postchaetal lobe length longer than chaetae…… 2

 - Posteior postchaetal lobe length shorter than chaetae…… 3

2. With long MxII polymorphic…….. *A. panamensis* Colbath, 1989

 - Without long MxII polymorphic…… *A. semimaculata* (Mooro, 1911)

3. Number of MxV teeth two……. *A.* (*Cenothrix*) *robusta* Zanol and Ruta, 2015

 - Number of MxV teeth one……. 4

4. With distal shape of MxI polymorphic…….. *A.* (*Cenothrix*) *mutans* (Chamberlin, 1919)

 - Without distal shape of MxI polymorphic…… 5

5. With both long MxII…… *A.* (*Arabella*) *pulvinata* Zanol and Ruta, 2015

 - Without both long MxII…….. 6

6. Distal shape of MxI both falcate…… 7

 - Distal shape of MxI have bifid……. 11

7. Shape of modified ventralmost chaeta tapering gradually to guard…… 8

 - Shape of modified ventralmost chaeta tapering abruptly to guard…… 10

8. Pygidium of cirri shape…… 9

 - Pygidium of swollen pad shape…… *Arabella* n. sp.

9. Pygidium of two cirri.…… *A. aracaensis* Steiner and Amaral, 2009

 - Pygidium of four cirri.…… *A. longicirrata* Hartmann–Schröder, 1979

10. Species restricted to the Galapagos Islands…… *A. monroi* Colbath, 1989

 - Species that are not geographically restricted…… *A. atlantica* Crossland, 1924

11. Distal shape of MxI right bifid…… *A. iricolor* (Montagu, 1804)

 - Distal shape of MxI left bifid…… 12

12. Ventral maxillary carrier length 1/2 dorsal…… *A. pectinata* Fauchald, 1970

 - Ventral maxillary carrier length longer than 2/3 dorsal…… *A. logani* Crossland, 1924

(*A. protomutans* Orensanz, 1990) – two species are possibly the same species (Steiner and Amaral, 2009).

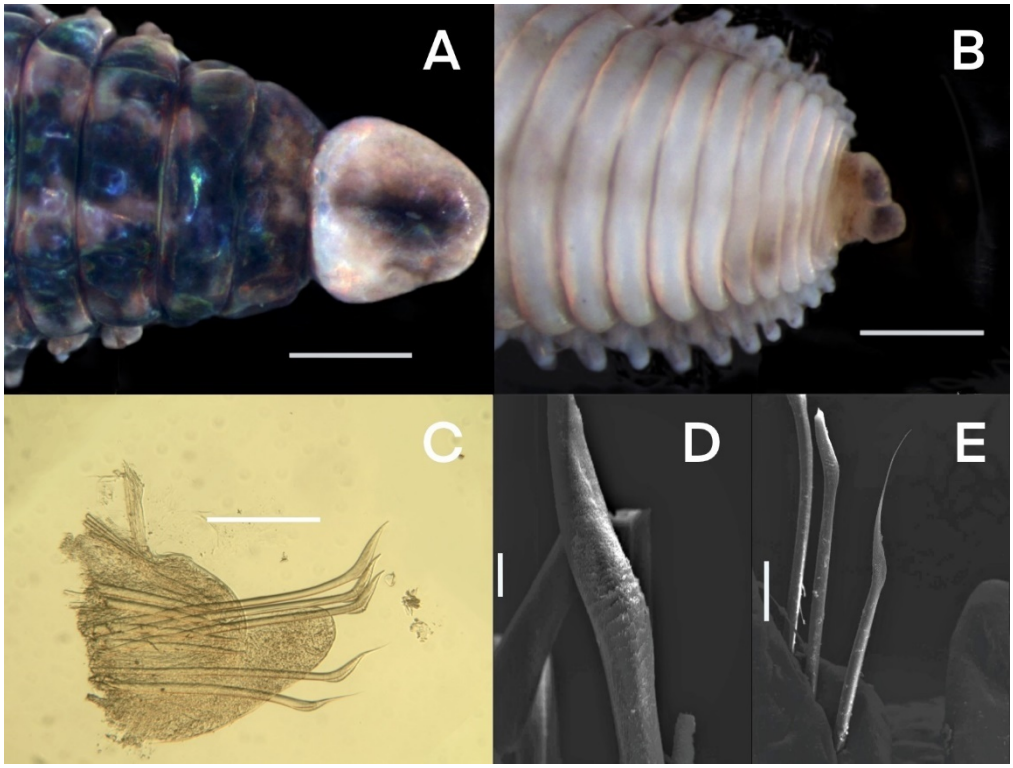

Fig. 3. *Arabella* n. sp. A, anterior region, dorsal view; B, pygidium; C, parapodium 225; D, serrated blade of medioventral chaeta (parapodium 150); E, modified ventralmost chaeta (parapodium 150). Scale bars: A, B = 1mm, C = 125µm, D = 10 µm, E = 50 µm.

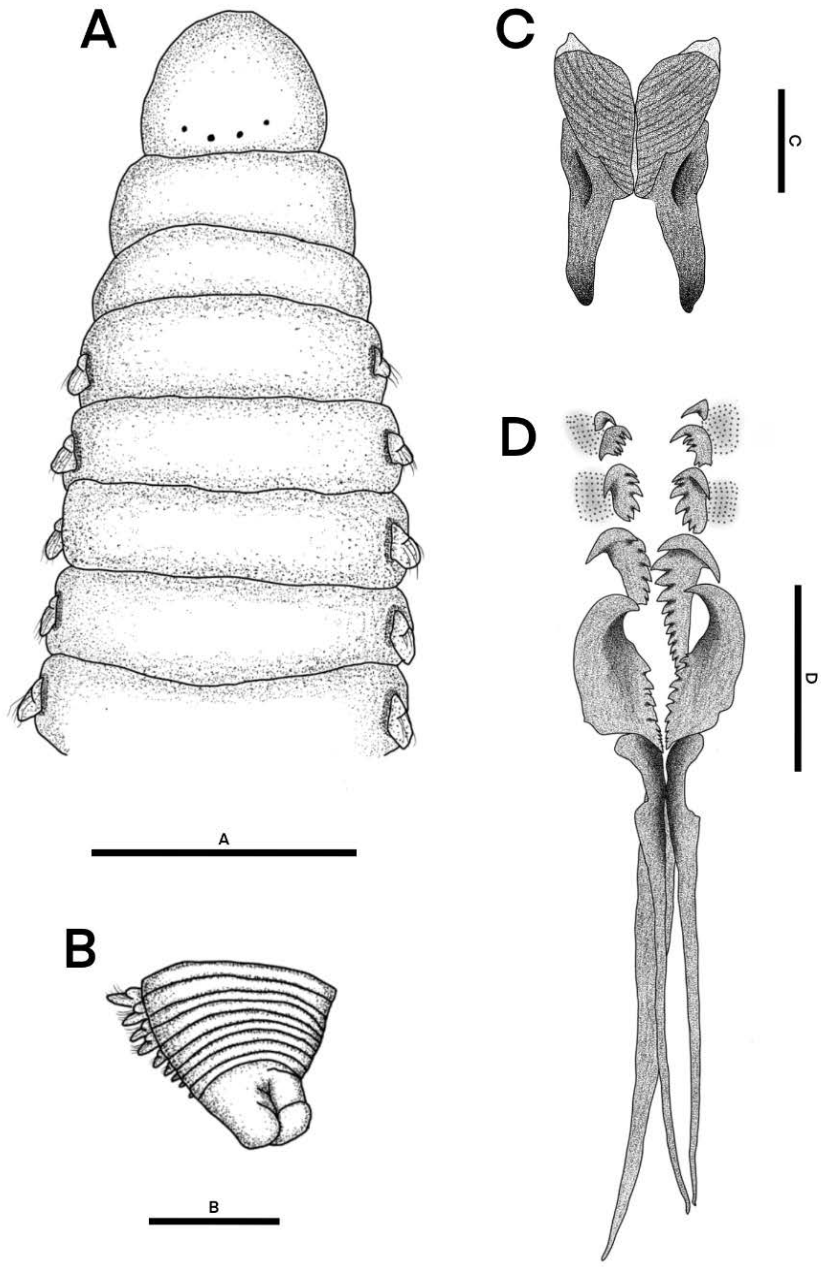

Fig. 4. *Arabella* n. sp. A, anterior region, dorsal view; B, pygidium; C, mandibles; D, maxillae. Scale bar: A = 3 mm; B = 1 mm; C = 1 mm; D = 2 mm.

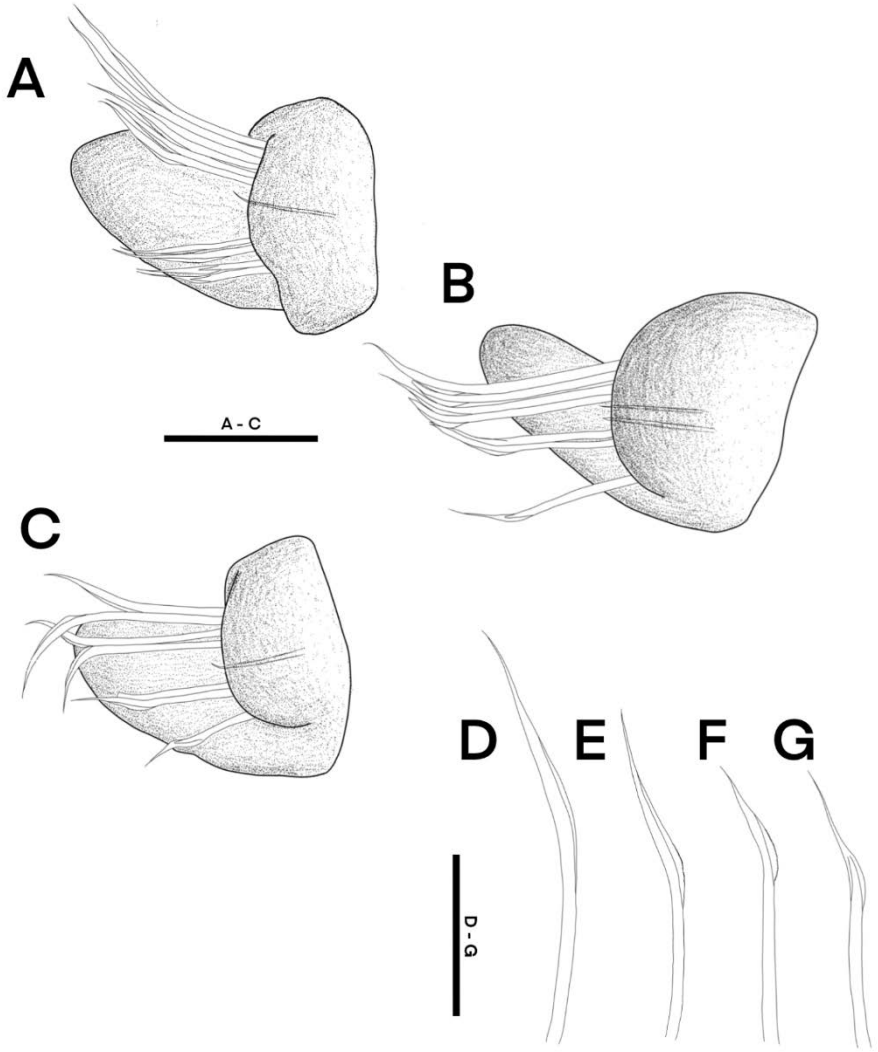

Fig. 5. *Arabella* n. sp. A, parapodium11; B, parapodium 263; C, parapodium 485; D, superior chaeta; E, mediodorsal chaeta; F, medioventral chaeta; G, modified ventralmost chaeta. Scale bar: A – C = 500 µm; D – G = 150 µm.

Table 1. Comparison of the morphological characteristics of the species currently assigned to *Arabella*.

Species	Type Locality	Maxillary carriers length of ventral in relation to dorsal	Shape of MxI	Long MxII	Number of MxV teeth	Posteior postchaetal lobe length in relation to chaetae	Shape of modified ventralmost chaeta	Pygidium	References
Arabella n. sp.	Korea, Yeongdeok	equal or longer	falcate (robust, gracile)	right	1+1	shorter	tapering gradually to guard	two swollen pads	Present study
A. iricolor (Montagu, 1804)	England, south coast of Devonshire	shorter	falcate, bifid (robust, gracile)	right	1+1	shorter	tapering gradually to guard	two cirri	Fauchal, 1970; Colbath, 1989 Bogantes, 2014; Zanol and Ruta, 2015
*A. semimaculata (*Mooro, 1911)	Australia, Great Barrier Reef, Queensland	equal or longer	falcate (robust, gracile)	right	1+1	longer	tapering gradually to guard	two or four cirri	Mooro, 1911; Blake, 1995
A. (*Cenothrix*) *mutans* (Chamberlin, 1919)	Chile, Easter Island	2/3 shorter	polymorphic (polymorphic)	polymorphic	1+1	shorter	tapering abruptly to guard	four cirri	Chamberlin, 1919; Zanol and Ruta, 2015
A. atlantica Crossland, 1924	Cape Verdean Islands	unknown	falcate (robust, gracile)	right	1+1	shorter	tapering abruptly to guard	unknown	Colbath, 1989; Steiner and Amaral, 2009
A. logani Crossland, 1924	Egypt, Gulf of Suez	shorter	bifid, falcate (robust, gracile)	right	1+1	shorter	tapering gradually to guard	two swollen pads	Colbath, 1989; Steiner and Amaral, 2009

Table 1 (Continued)**.**

Species	Type Locality	Maxillary carriers length of ventral in relation to dorsal	Shape of MxI	Long MxII	Number of MxV teeth	Posteior postchaetal lobe length in relation to chaetae	Shape of modified ventralmost chaeta	Pygidium	References
A. pectinata Fauchald, 1970	Mexico, Baja California, Pacific Ocean	1/2 shorter	bifid, falcate (unknown)	right	1+1	shorter	tapering gradually to guard	unknown	Fauchald, 1970
A. longicirrata Hartmann–Schröder, 1979	Portugal, Atlantic Ocean	unknown	falcate (robust, gracile)	right	1+1	shorter	tapering gradually to guard	four cirri	Hartmann–Schröder, 1979
A. monroi Colbath, 1989	Ecuador, Galapagos Islands	shorter	falcate (robust, gracile)	right	1+1	shorter	tapering abruptly to guard	two swollen pads	Colbath, 1989
A. panamensis Colbath, 1989	Costa Rica, Golfo de Nicoya	shorter	falcate (polymorphic)	polymorphic	1+1	longer	tapering abruptly to guard	two cirri	Colbath, 1989
A. protomutans Orensanz, 1990	Argentina, Golfo San José	equal or shorter	bifid, falcate (robust, gracile)	right	1+1	shorter	tapering gradually to guard	unknown	Orensanz, 1990; Steiner and Amaral, 2009
A. aracaensis Steiner and Amaral, 2009	Brazil, State of São Paulo, Araçá Beach	2/3 shorter	falcate (robust, gracile)	right	1+1	shorter	tapering gradually to guard	two cirri	Steiner and Amaral, 2009

Table 1 (Continued)**.**

Species	Type Locality	Maxillary carriers length of ventral in relation to dorsal	Shape of MxI	Long MxII	Number of MxV teeth	Posteior postchaetal lobe length in relation to chaetae	Shape of modified ventralmost chaeta	Pygidium	References
A. (*Arabella*) *pulvinata* Zanol and Ruta, 2015	Australia, Lizard Island, Mangrove beach	2/3 shorter	falcate, bifid (gracile)	both	1+1	shorter	tapering gradually to guard	four cirri	Zanol and Ruta, 2015
A. (*Cenothrix*) *robusta* Zanol and Ruta, 2015	Australia, Lizard Island, Big Vicki's reef	ventral carrier not observed	falcate (robust, gracile)	right	2+2	shorter	tapering abruptly to guard	two swollen pads	Zanol and Ruta, 2015

Order Eunicida Dales, 1962 털갯지렁이목

Family Oenonidae Kinberg, 1865 홍점갯지렁이과

Genus *Oenone* Lamarck, 1818

2. *Oenone fulgida* (Lamarck, 1818)

Oenone fulgida: Crossland, 1924: 85, Day, 1967: 426, Zanol and Ruta, 2015: 766: Fig. 10

Material examined. Korea: 1 ind. (incomplete), Haengwon-ri, Gujwa-eup, Jeju-si, Jeju-do (33°33′29″N, 126°49′51″E), 24 August 2023, depth 10–15, SCUBA diving.

Diagnosis. Prostomium anteriorly with four eyes on posterior margin of prostomium; ventral eyes absent, with three antennae. Peristomium forming single ring. Maxillary carriers long and slender, and without ventral carrier absent. MxI symmetric, distal shapes both falcate. Prechaetal lobe shorter than postchaetal. All chaetae limabate capillary, with subacicular hooks bidentate.

Description. Body 1.7 mm wide, slender; body color yellow to orange (Fig. 6A).
Prostomium rounded, flated, similar length and wide, four eyes, two lateral eyes larger than two median eyes; arranged in base of dorsal prostomium, ventral eyes absent, with three antennae posteriorly the eyes; covered by anterior of peristomium. Peristomium single ringed; ring wider than prostomium, longer than next chaetigers (Figs. 6A to 6C).

Mandibles darkly, mandible carriers long, slender; longer than cutting plate (Fig. 7A). Maxillary carriers long, slender, pair of ventral carriers absent dorsal carrier, maxillae with five pairs of plates, MxI distal shape with both falcate, symmetric, MxII and left MxIII with additional anterior teeth, Maxillary formula: (1, 7) + (1, 7), 7 + 8, 5 + 6, 6 + 7, 1 + 1 (Fig. 7B).

Prechaetal lobe twice as long as postchaetal lobe; prechatal lobe conical, postchaetal lobe rounded. Dorsal cirri flated, foliaceous shape, aiculate absent; size increased from anterior to

median. Chaetae only limbate capillary shape, subacicular hooks bidentate; hooded hook (Fig. 6A; Figs. 7C to 7E).

Remarks. Characteristic features of *Oenone* are with two pairs of eyes, three antennae, dorsal cirri, and subacicular hooks. These characteristics are distinguished from *Arabella* and *Drillolonereis*, previously reported as oenonid genera in the Korean fauna. In the genus *Oenone*, only two species, *O. fulgida* and *O. ventrioculata* Zanol and Ruta, 2015, are currently known. These two species can be distinguished from each other by the following features: 1) prostomium anterior region without ventral eyes (*vs*. with a pair of ventral eyes in the latter); 2) shape of MxI symmetric or asymmetric (*vs*. only asymmetric in the latter) (Table 2; Crossland, 1924; Day, 1967; Zanol and Ruta, 2015).

Habitat. Subtidal, seaweed bed and coral reef.

Distribution. Worldwide.

Order Eunicida Dales, 1962 털갯지렁이목

Family Onuphidae Kinberg, 1865 집갯지렁이과

Genus *Diopatra* Audouin and Milne Edwards, 1833 집갯지렁이속

3. *Diopatra* n. sp.

Material examined. *Type locality*: Korea. Doksan–ri, Ungcheon–eup, Boryeong–si, Chungcheongnam–do (36°14′24″N, 126°31′38″E), 28 October 2022, intertidal sandflat. ***Holotype.*** complete ind. ***Paratype.*** 1 ind. (complete); 1 ind. (incomplete); 1 ind. (complete). ***Non–type materials.*** Korea: 1 ind. (incomplete), Geumho–ri, Sani–myeon, Haenam–gun,

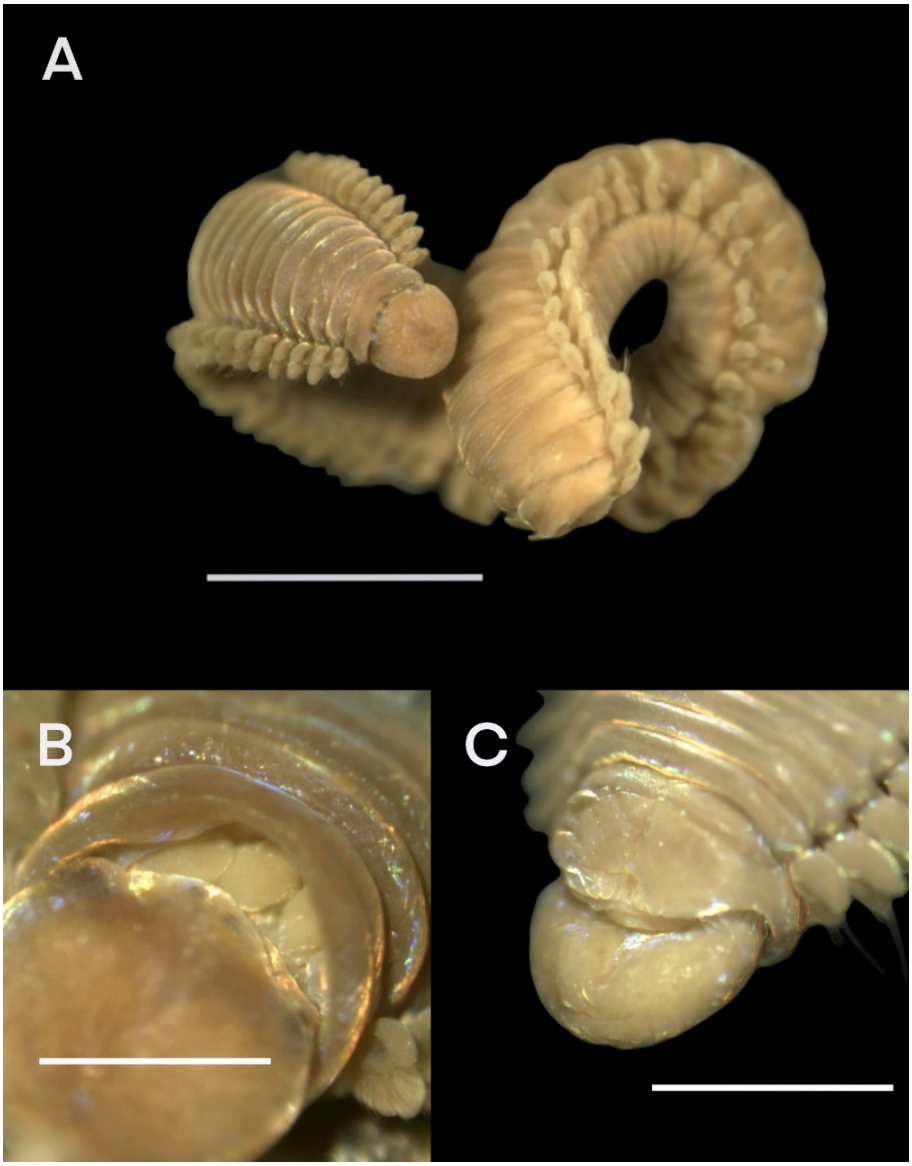

Fig. 6. *Oenone fulgida* (Lamarck, 1818). A, whole body; B, antennae; C, anterior region, ventral view. Scale bar: A = 3mm; B = 0.5 mm; C = 1 mm.

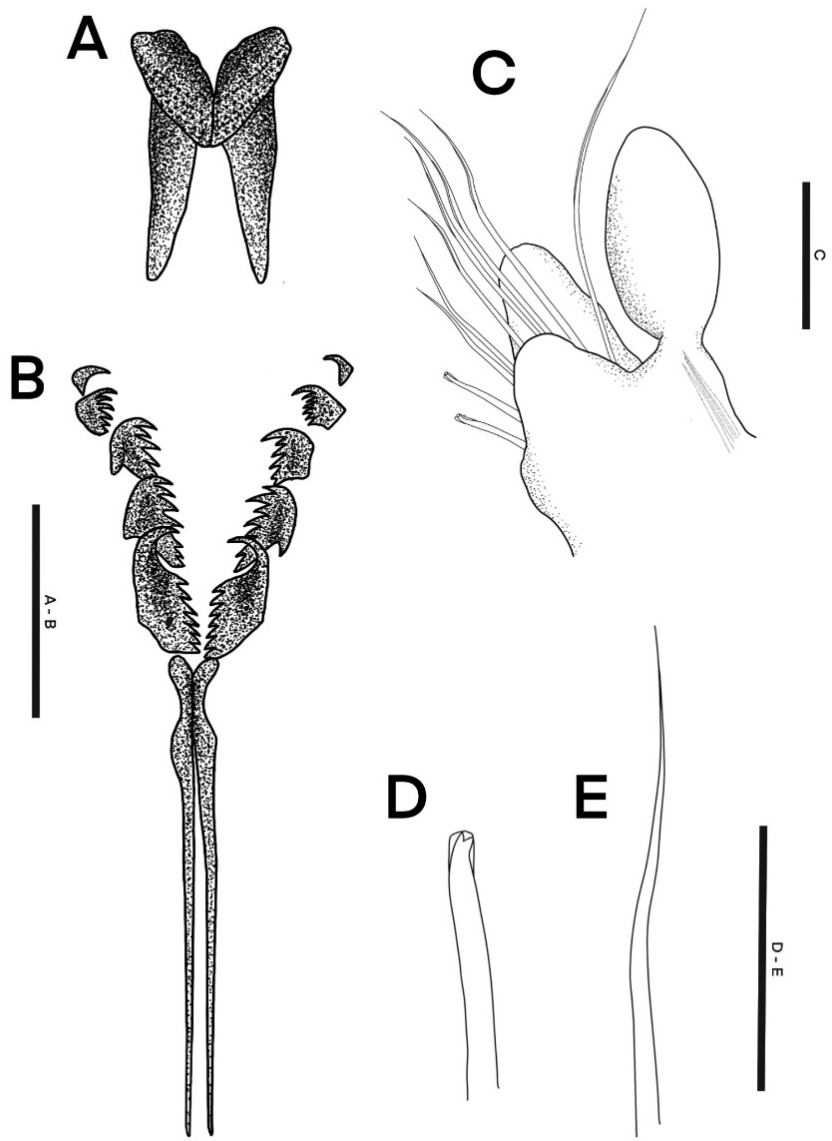

Fig. 7. *Oenone fulgida* (Lamarck, 1818). A, mandibles; B, maxillae; C, parapodium 20; D, subacicular hooks; E, limbate capillary chaetae. Scale bar: A, B = 1 mm; C = 250 µm, D–E = 125 µm.

Table 2. Comparison of the morphological characteristics of the species currently assigned to *Oenone*.

Species	Type Locality	Prostomium ventral eyes	Mandible cutting plates	Shape of MxI	Anteriormost tooth of MxI in relation to other teeth of MxI	Pygidium cirri width of ventral in relation to dorsal	References
O. fulgida (Lamarck, 1818)	Red Sea, Gulf of Suez	absent	flat	symmetric or asymmetric	equal	equal	Present study; Lamarck, 1818 Crossland, 1924; Day, 1967; Zanol and Ruta, 2015
O. ventrioculata Zanol and Ruta, 2015	Australia, Lizard Island, Bird and South Island	present	with one indentation	asymmetric	lager	twice	Zanol andRuta,2015

Jeollanam–do (34°41’57.6”N 126°22’1.2”E), 8 April 2023, intertidal sandflat; 2 ind. (incomplete), Gyeokpo–ri, Byeonsan–myeon, Buan–gun, Jeollabuk–do (35°38’3.1”N 126°27’58.5”E), 8 May 2023, intertidal sandflat; 2 ind. (incomplete), Unsan–ri, Byeonsan–myeon, Buan–gun, Jeollabuk–do (35°39’42.5”N 126°30’15.8”E), 6 May 2023, intertidal sandflat; 2 ind. (incomplete), Mohang–ri, Sowon–myeon, Taean–gun, Chungcheongnam–do (36°45’3.5”N 126°7’46.7”E), 21 May 2023, intertidal sandflat; 3 ind. (incomplete), Hagampo–gil, Wonbuk–myeon, Taean–gun, Chungcheongnam–d (36°54’0.8”N 126°12’35.8”E), 19 May 2023, intertidal sandflat.

Diagnosis. Prostomium anteriorly round, eyes absent, 3 antennae and 2 palps, 8–11 rings of ceratophores. Nuchal groove developed forming 3/4 circle. Peristomial cirri in one pair presence. Spiraled branchiae started in chaetiger 5. Postchaetal lobe of anterior parapodia split into upper and lower subulates. Tip of hooks with unidentate or bidentate, weakly oblique pectinate chaetae; 24–30 teeth. Mandibles with two distal indentations along edge; mandibular carriers with a brightly long line on inner side, MxIII with only left.

Description. Holotype, complete specimen (broken in two parts), length 175 mm, width 7 mm, with chaetigers 212. Paratype, Smallest incomplete specimen, width 5.5 mm; largest incomplete specimen, long 13.3 mm, width 7 mm, and with 215 chaetigers.

Body color of ethanol–fixed specimen anterior dorsal deep iridescent blue, posterior dorsal and ventral dark brown line in the center; no distinct color pattern, thicker from anterior to medial, after that body of similar width and abruptly tapering in the posterior (Figs. 8A and 8B).

Prostomium two subulate front lips and two rounded upper lips, two ceratophores palps, three ceratophores antennae; divided into a pair of lateral antennae and medial antennae, ceratophore rings 8–11, lateral antennae long to chaetigers 7–8, antenna1 styles with about 30 irregular lengthwise rows of sensory buds, flat buds, medial antenna long to 8–9 chaetigers, nuchal groove forming 3/4 circles on the posterior margin, peristomium dorsal one pair of

peristomial cirrus as long as chaetiger 1(Figs. 8A and 8B).

Mandible cutting plates white, distal two indentations, high calcareous, mandibular carriers brightly long line on inner side. MxI with both falcate and robust, MxIII only left, maxillary formula of one paratype: MxI = 1+1; MxII = 10+9; MxIII = 7+0; MxIV = 7+10; MxV = 1+1 (Figs. 9A and 9B).

Parapodia six pairs anterior with prechaetal lobe and postchaetal lobe; subulate shape, parapodia modified in first chaetigers 5, prechaetal lobe deeply incised; dorsal larger than to ventral and ventral part knob–like shape, absent from chaetigers 16–19. Postchaetal lobe divided into upper and lower, postchaetal lobe length of chaetiger 1 upper lobe longer than lower; lower lobe smaller after chaetiger 1 and absent after chaetiger 6. Dorsal cirri and ventral cirri subulate shape; ventral cirri absent after chaetiger 6, spiraled branchiae from chaetiger 5 best developed on chaetigers 7–9, 10–13 whorls, reaching to peristomium or chaetiger 1 when anteriorly extended, absent from chaetigers 54–58 (Figs. 8C and 8D; Figs. 9C to 9F).

Modified parapodia (chaetigers 1 to 4) limbate capillary chaetae and hooks. Pseudocompound hooks only bidentate, large median pseudocompound hook without hooded; slightly bidentate, median pseudocompound hook with or without hooded, inferior pseudocompound hook almost with hooded, simple hook unidentate. Unmodified parapodia with pectinate chaetae, pectinate chaetae number of teeth 24–30; weakly oblique combs. Subacicular hooks from chaetigers 17 – 20; bidentate (Figs. 8E to 8H; Figs. 10A to 10H).

Pygidium with 2 pairs of cirri, pair of dorsal longer than that of ventral.

Remarks. *Diopatra* n. sp. is characterized by the anterior postchaetal lobe divided into the upper and lower lobes. This is a relatively rare characteristic feature that is appeared in several *Diopatra* species (*D. chiliensis* Quatrefages, 1866, *D. sugokai* Izuka, 1907, *D. dexiognatha* Paxton and Bailey-Brock, 1986, *D. gesae* Paxton, 1998, *D. kristiani* Paxton, 1998, *D. biscayensis* Fauchald, Berke and Woodin, 2012, *D. mariae* Paxton and Arias, 2017, *D. mellea* Paxton and Arias, 2017) (Izuka, 1907; Paxton and Bailey-Brock, 1986; Paxton, 1998; Fauchald *et al.*, 2012; Arias and Paxton, 2015;

Paxton and Arias, 2017; Hektoen *et al*., 2022). Among them, *D. sugokai* and *D. biscayensis* are differentiated from other species by having a mandible cutting plates indentation. That is, *D. sugokai* has one indentation of the mandible cutting plates and *D. biscayensis* has two. In this respect, *Diopatra* n. sp. is much similar to *D. biscayensis* in having two indentations of the mandible cutting plates. However, the new species can be distinguished from the latter by the following characteristics: 1) mandibular carriers with a brightly long line on inner side (*vs*. without in the latter) (Table 3; Fauchald *et al*., 2012; Arias and Paxton, 2015; Hektoen *et al*., 2022).

Habitat. Intertidal sandflat.

Distribution. Korea.

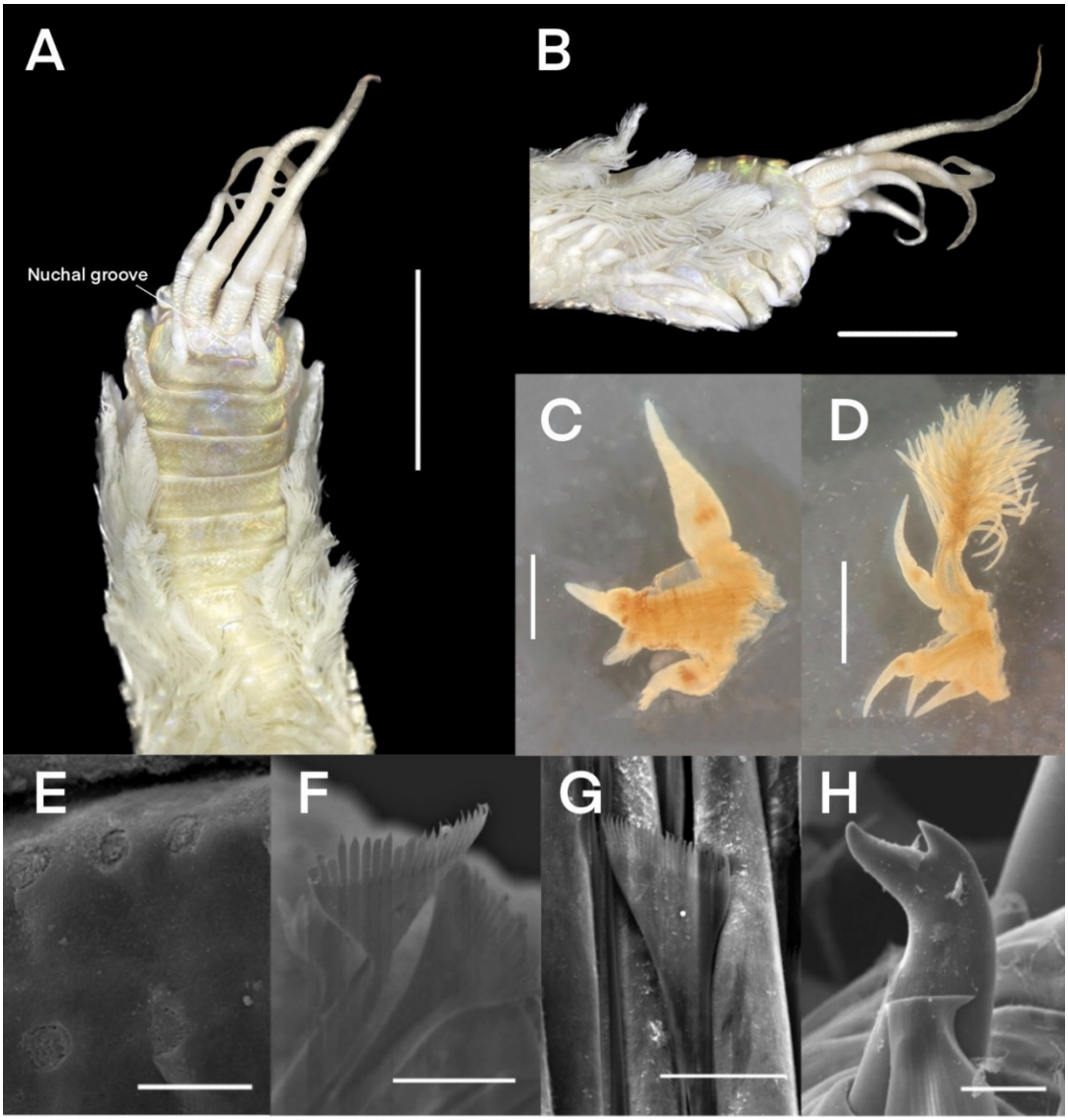

Fig. 8. *Diopatra* n. sp. A, anterior region, dorsal view; B, anterior region, lateral view; C, parapodium 1; D, parapodium 5; E, sensory buds; F, pectinate chaetae (parapodium 9); G, pectinate chaeta (parapodium 26); H, subacicular hook (parapodium 9). Scale bar: A = 20 mm; B = 5mm; C = 1 mm; D = 2 mm; E = 20 µm; F = 20µm; G = 40µm; H = 40µm.

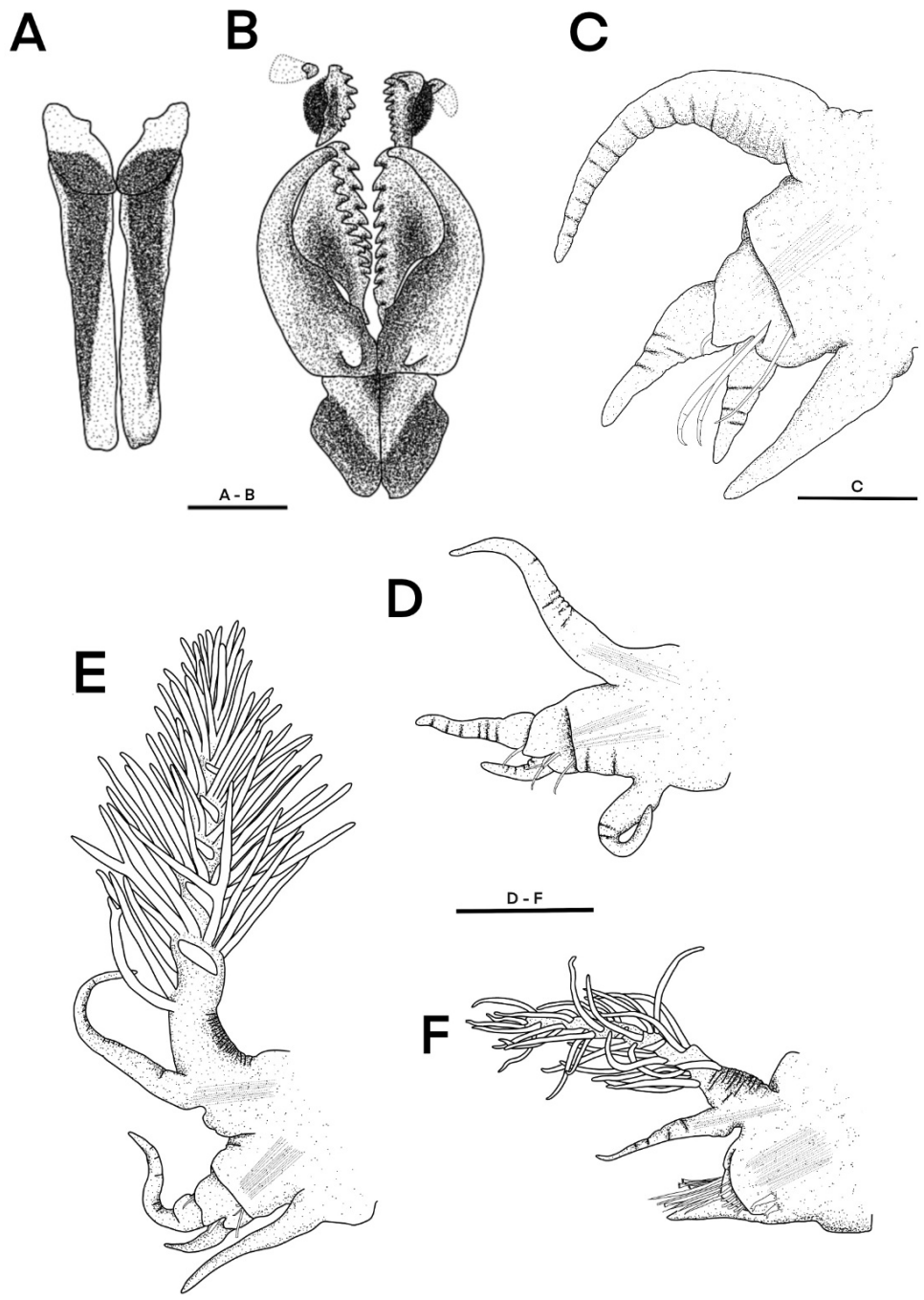

Fig. 9. *Diopatra* n. sp. A, mandibles; B, maxillae; C, parapodium 1; D, parapodium 3; E, parapodium 5; F, parapodium 27. Scale bar: A, B = 1 mm; C = 1 mm, D – F = 2 mm.

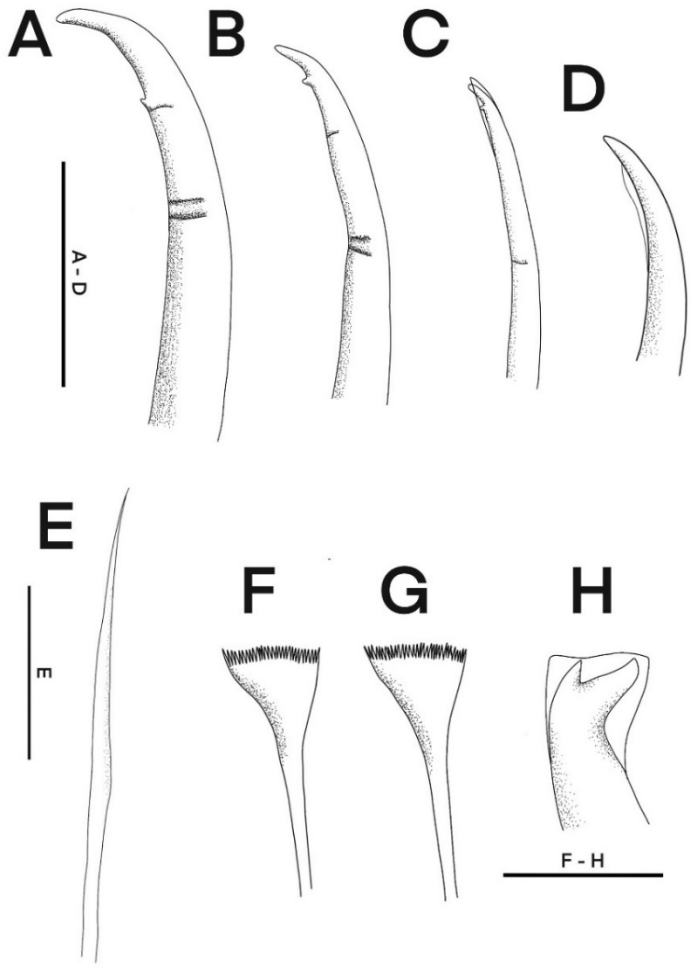

Fig. 10. *Diopatra* n. sp. A, large median pseudocompound hook (parapodium 1); B median pseudocompound hook (parapodium 1); C, inferior pseudocompound hook (parapodium 1); D, single hook (Parapodium 5); E, limbate capillary chaeta (parapodium 5); F, pectinate chaeta (parapodium 10); G, pectinate chaeta (parapodium 47); H, subacicular hook. Scale bar: A, B = 150 µm; C = 300 µm, D – F = 100 µm.

Table 3. Comparison of the morphological characteristics of the species with two postchaetal lobes currently assigned to *Diopatra*.

Species	Type Locality	Number of ceratophore rings	Nuchal grooves	Mandibles	MxIII	Lower postchaetal lobe	Number of teeth pectinate chaetae	Tip of hooks	References
Diopatra. n. sp.	Korea, Boryeong	8-11	forming 3/4 circles	two distal indentations along edge	only left	subulate	24-30	unidentate, bidentate	Present study
D. chiliensis Quatrefages, 1866	Chile,Pacific Ocean	9-12	cresentic	oblique lighter stripe on shafts	only left	subulate or knob-like	15-20 obilque	bidentate, tridentate	Quatrefages, 1866; Paxton, 1998; Arias and Paxton, 2015
D. sugokai Izuka, 1907	Japan, Pacific Ocean	7-12	forming 3/4 circles	median distal indentation	left and both	subulate	7-30, various	bidentate	Izuka, 1907; Imajima, 1967; Paxton, 1998; Hektoen *et al*., 2022
D. dexiognatha Paxton and Bailey-Brock, 1986	Hawaii, Pacific Ocean	6-9	semicircular	slender shafts, high cutting plates	both	subulate	15-20	bidentate	Paxton and Bailey -Brock, 1986; Paxton and Arias, 2017
D. gesae Paxton, 1998	Chile, Punta Ronca	9-11	cresentic	proximaml ventral bulge	only left	subulate or knob-like	15-18	bidentate, coarsely serrated	Paxton, 1998
D. kristiani Paxton, 1998	Panama, Balboa	8-11	forming 3/4 circles	black long line on inner side	left and both	subulate	16-20	bidentate	Paxton, 1998

Table 3 (Continued)**.**

Species	Type Locality	Number of ceratophore rings	Nuchal grooves	Mandibles	MxIII	Lower postchaetal lobe	Number of teeth pectinate chaetae	Tip of hooks	References
D. biscayensis Fauchald, Berke and Woodin, 2012	France, Bay of Biscay	6-10	forming 3/4 circles	two distal indentations along edge	only left	subulate	25-32	unidentate, bidentate	Fauchald *et al*., 2012; Arias and Paxton, 2015; Hektoen *et al*., 2022
D. mariae Paxton and Arias, 2017	Spain, Canary Islands, Lanzarote	7-9	crescentic to semicircular	unknown	only left	knob-like	18-22	bidentate	Paxton and Arias, 2017
D. mellea Paxton and Arias, 2017	Spain,Canary Islands, Las Palmas,	12-13	crescentic to semicircular	calcareous part dissolved	only left	subulate or knob-like	4-11	bidentate	Paxton and Arias, 2017

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ABSTRACT

Taxonomic Study on the Oenonid and Onuphid Polychaetes (Polychaeta: Oenonidae, Onuphidae) in Korea

Seong Hun Kang

Advisor: Prof. Seong Myeong Yoon

Department of Global Bio-Convergence

Graduate School of Chosun University

The Oenonidae Kinberg, 1865 and Onuphidae Kinberg, 1865 include the largest and most found groups in the marine benthic invertebrate communities, and are known to perform important roles as predators and prey in the food web. In Korean waters, two species belonging two genera have been known in Oenonidae, while five species belonging four genera in Onuphidae. Among these known species, especially *Arabella iricolor* (Montagu, 1804) and *Diopatra sugokai* Izuka, 1907 have not been well studied morphologically in Korea. The aim of the present study is to investigate of these groups to accurate identification and classification of the species. The taxonomic study was conducted on the specimens of oenonids and onuphids, collected at 28 localities from April 2021 to August 2023 in Korea, with those preserved in the Department of Biology, Chosun University. The study reveals the following results: (1) Two new species are new to science (*Arabella* n. sp.**,** *Diopatra* n. sp.); (2) One species is newly reported in Korea (*Oenone fulgida* (Lamarck, 1818)). *Arabella* n. sp. is characterized by its ventral maxillary carrier longer than or equal to dorsal, distal shape of MxI both falcate, and ventralmost chaeta tapering gradually to guard, with pygidium of swollen pads. These

characteristics distinguish it from other *Arabella* species, including *Arabella iricolor*. *Diopatra* n. sp. is characterized by its distal mandible with two indentations, mandibular carriers with brightly long lines on the inner side, and pectinate chaetae constant number of teeth 24-30. These characteristics distinguish it from other *Diopatra* species, including *Diopatra sugokai*. *Oenone fulgida* is newly recorded in Korean fauna and is characterized by the without ventral eyes of prostomium and MxI of symmetry. These characteristics distinguished it from other *Oenone* species. This study provides detailed descriptions and illustrations for three species. In addition, morphological characteristics of these species are compared and discussed with related species, with a key to them.

Keywords: Korea, Oenonidae, Onuphidae, new species, morphology analysis, taxonomy

감사의 글

2016 년도 조선대학교에 입학해 8 년동안 학교를 다녔으며 이제는 석사 과정을 마쳐 졸업하게 될 시간이 된 게 감회가 새롭습니다. 처음 실험실에 들어왔을 때는 무엇을 해야 하는지 모르고 그저 새로운 동물을 찾고 싶다는 마음만을 갖고 왔습니다. 돌아보니 정말 계획도 생각도 별로 없었네요. 이런 제가 석사학위를 갖게 도움을 분들께 감사한 마음을 글로 남기고 싶어 적어보려 합니다.

먼저 대책 없는 저를 이끌어 주시고 실험에 필요한 모든 지원과 논문 작성과정에 아낌없이 조언해주시고 필요한 야단도 치시며 꼼꼼히 지도해주신 윤성명 교수님께 정말 감사드립니다. 정말 교수님이 아니셨으면 졸업 못했습니다. 이어 졸업에 가장 중요한 학위심사의 위원장을 맡아 주신 이정섭 교수님, 위원을 맡아 주신 송상기 교수님 감사드립니다. 그리고 갯지렁이 분류군을 정하는데 도움을 주시고 모든 실험 과정과 조언, 논문을 쓰는 방법, 읽어볼 논문을 추천과 그 외 자잘한 고민들에 조언해주시고 도와 주신 실험실 선배인 최현기 박사님, 성훈이 형, 건혁이 형 감사드립니다. 논문에 관한 질문은 못 드렸었지만 만날 때 맛있는 밥을 사 주셨던 정태원 박사님, 김종국 박사님도 감사드립니다. 그 다음 실험실에 있으면서 모르는 모든 것들과 현장에서 알아야하는 모든 것을 알려준 주원이 형 감사드립니다. 실험실에 있던 3 년 같이 먹고 자고 일하고 지냈던 유석이형, 이주, 목인이 셋 모두 4 학년이 되어서야 들어온 저를 문제없이 적응하게 해주는데 노력해준 걸 고맙게 느끼고 있습니다. 왠만한 일들은 자기가 해주려 하는 착한 유석이형, 뭐든 꼼꼼하게 확인해주는 목인이, 생각 못하고 있던 것들 알려주는 이주 모두 감사드립니다. 사랑하는 가족들 제 인생을 지원해주시고 돌봐 주신 부모님, sample sorting 도와주다가 미기록종을 찾은 나랑 너무 잘 맞는 성호, 그냥

귀여워서 내 정신을 힐링 해주는 은비 정말 감사드립니다. SEM 촬영을 알려주신 김광석 박사님, Fig.작업과 개인 채집을 도와줬던 우리 감사드립니다. 이외에도 학교에서 만나면 인사 해주시고 모르는 것도 알려준 여러 생명과학과 교수님들과 선, 후배님들 그리고 바빠서 연락도 못하는데 만나면 반겨주는 친구들 모두 감사드립니다. 마지막으로 지금까지 포기 안하고 계속 노력해준 저 자신한테도 고맙다는 말을 하고 이만 물러나겠습니다. 다시 한번 이 모든 분들에게 감사한 마음을 드립니다.