Two new ectoparasitic isopods (Isopoda, Cymothoida, Cymothooidea) from Korean waters with a note on geographical distributions of *Rocinela* and *Gnathia* species

Comment [K1]: Not found in any host, how you can say that it is ectoparasitic?

Comment [K2]: Two times isopod used, revise.

Comment [K3]: Authority and year?

Title needs revision, not correct.

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ABSTRACT

Two new ectoparasitic isopods, *Rocinela excavata* **sp. nov.** and *Gnathia obtusispina* **sp. nov.**, are ~~newly~~ reported from South Korea. *Rocinela excavata* **sp. nov.** is distinguishable from its related species by ~~a~~ having laterally stepped rostrum, separated eyes, eight robust setae on the propodal blade, and four or five blunt robust setae on the merus in pereopods 1–3. *Gnathia obtusispina* **sp. nov.** differs from its congeners by having its body covered with numerous tubercles and setae, a tooth-like blunt spine on the cephalon near the eye, and the frontal border with two inferior frontolateral processes. Additionally, geographical distributions of the genera *Rocinela* and *Gnathia* are discussed in this study.

Subjects Taxonomy

Keywords ectoparasite, *Gnathia,* isopods, morphology, *Rocinela,* taxonomy, South Korea

INTRODUCTION

Within isopod taxa, the superfamily Cymothooidea Leach, 1814 including families Aegidae White, 1850 and Gnathiidae Leach, 1814 is one of representative parasitic groups (*William and Boyko 2012*; *Smit et al. 2019*). Although most cymothooid families are obligate associated with marine fishes and invertebrate hosts, both Aegidae and Gnathiidae are known to be temporary ectoparasites that can attach to fishes in particular life history (*Bruce, 2009*; *Svavarsson & Bruce, 2012*; *William & Boyko, 2012*; *Cardoso et al., 2017*; *Smit et al., 2019*). Aegids are also regarded as free-living micro-predators because they often detach from their hosts and spend most of the time free-living on the seafloor (*Bruce, 2009*; *William & Boyko, 2012*; *Smit et al., 2019*). Similarly, adults of gnathiid isopods are free-living (with non-feeding) on cryptic habitats of sponges, dead corals, barnacle nests, and polychaete's tubeworms (Kopuz et al. 2011) whereas their juveniles show a hematophagous life cycle (*Svavarsson & Bruce, 2012*; *William & Boyko, 2012*; *Smith et al., 2019*).

Aegidae morphologically differs from other isopod taxa in terms of the maxillule having robust setae distally, the maxillipedal palp articles 3 and 4 having conspicuous recurved robust setae distally, and having prehensile pereopods 1–3 and ambulatory pereopods 4–7. Among members of this family, the genus *Rocinela* Leach, 1818 is distinguishable from other genera by

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having pleonite 1 not abruptly narrowing than pereonite 7 and a 3-articled maxillipedal palp (*Bruce, 2009*). Although it is difficult to distinguish *Rocinela* species from each other, the shape of the frontal margin of cephalon and the pereopodal armature are most helpful in identifying species (*Brusca & France, 1992*). So far, seven *Rocinela* species have been recorded from the Far East: *R. belliceps* (Stimpson, 1864) from the Sea of Okhotsk, Russia; *R. maculate* Schioedte & Meinert, 1879 from the East Sea, Russia and South Korea; *R. japonica* Richardson 1898 from the Hakodate Bay, Japan; *R. affinis* Richardson, 1904 from the Shizuoka, Japan; *R. angustata* Richardson, 1904 from the Manazuru, Japan; *R. niponia* Richardson, 1909 from the Sado Island, Japan; and *R. lukini* Vasina, 1993 from the Sea of Okhotsk, Russia (*Schioedte & Meinert, 1879*; *Richardson, 1898*, *1904*, *1909*; *Vasina, 1993*; *National Institute of Biological Resources, 2012*).

Comment [K11]: All as parasites from the host?

Gnathiids show highly polymorphic forms depending on their developmental stages. Their adults exhibit considerable sexual dimorphism (*Ota, 2014*; *Smit et al., 2019*). They are distinguishable from other cymothooids largely based on adult male's characteristics of having remarkably enlarged mandibles and only five pairs of pereopods (*Svavarsson & Bruce, 2012*; *Smit et al., 2019*). Among the gnathiid genera, the genus *Gnathia* Leach, 1814 can be distinguished from others by its male's characteristics such as a transverse frontal border on the cephalon having frontal processes, a 2- or 3-articeld broad pylopod, and non-elongated mandibles having dentate blades (*Cohen & Poore, 1994*; *Song & Min, 2018*). Eleven *Gnathia* species have been reported in the Far East: *G. tuberculata* Richardson, 1909 from Nanao, Japan; *G. derzhavini* Gurjanova, 1933 from Askold Island, Russia; *G. rectifrons* Gurjanova, 1933 from the East Sea, Russia; *G. schmidti* Gurjanova, 1933 from the Bay of Vladimir, Russia; *G. bungoensis* Nunomura, 1982 from the Saeki Bay, Japan; *G. nasuta* Nunomura, 1992 from Kumamoto and Okinawa Islands, Japan; *G. sanrikuensis* Nunomura, 1998 from the Otsuchi Bay, Japan; *G. capillata* Nunomura & Honma, 2004 from Sado Island, Japan; *G. mutsuensis* Nunomura, 2004 from Asamushi, Japan; *G. gurjanovae* Golovan, 2006 from Peter the Great Bay, Russia; and *G. koreana* Song &Min, 2018 from Geomundo Island, Korea (*Boyko et al., 2008*; *Song & Min, 2018*; *Shodipo et al., 2021*).

In this study, we report two ectoparasitic isopods, *Rocinela excavata* **sp. nov.** and *Gnathia obtusispina* **sp. nov.** from Korean waters with their detailed descriptions and illustrations. Geographical distributions of these two genera are also discussed.

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MATERIAL AND METHODS

All materials were collected at the bottom of sublittoral zones using Smith-McIntyre grab and SCUBA diving without a host. *Rocinela excavata* **sp. nov.** was sampled from sandy-mudflats. *Gnathia obtusispina* **sp. nov.**, was collected from the bedrock detaching the seaweeds. These collected samples were immediately fixed in 95% ethyl alcohol and then transferred to the laboratory. Transferred samples were sorted from the sediment and then observed and dissected under a dissecting microscope (Olympus SZH-ILLD, Japan). Measurements and drawings of materials were conducted with the aid of a drawing tube on a compound microscope (Olympus, BX50, Japan) or the dissecting microscope. Pencil drawings were digitally scanned, inked, and arranged using a tablet and Adobe Illustrator CS6 as mentioned in *Colemen (2003, 2009)*. All examined type series and additional material were moved into each small glass vial filled with 95% ethanol and deposited at the National Institute of Biological Resource (NIBR), South Korea.

The electronic version of this article in Portable Document Format (PDF) will represent a published work according to the International Commission on Zoological Nomenclature (ICZN), and hence the new names contained in the electronic version are effectively published under that Code from the electronic edition alone. This published work and the nomenclatural acts it contains have been registered in ZooBank, the online registration system for the ICZN. The ZooBank LSIDs (Life Science Identifiers) can be resolved and the associated information viewed through any standard web browser by appending the LSID to the prefix http://zoobank.org/. The LSID for this publication is: [urn:lsid:zoobank.org:pub:7A53937A-F2EB-49C7-B8DA-F0AA36241310]. The online version of this work is archived and available from the following digital repositories: PeerJ, PubMed Central and CLOCKSS.

RESULTS

Taxonomy

Order Isopoda Latreille, 1817

Suborder Cymthoida Wägele, 1989

Superfamily Cymothooidea Leach, 1814

Family Aegidae White, 1850

Genus *Rocinela* Leach, 1818

Comment [K13]: How could you say as ectoparasite? Parasites from plankton sample? Many parasitic copepods are reported from plankton samples, is it like that?

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Rocinela excavata sp. nov.
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Figures 1–3

Type material.—Holotype, designated here: South Korea: ♂, 19.3 mm, Chujado Island (33°58′50″N, 126°20′23″E), Chuja-myeon, Jeju-si, Jeju-do, 15 January 2019, 30–40 m, S.H. Kim leg., Smith-McIntyre grab, VSJAIV0000000472. Paratype: 1♂, the same location as holotype, NIBRIV0000895341.

Diagnosis. Rostrum truncated apically and stepped laterally; eyes separated each other; pereopods 1–3 with 8 robust setae on propodal blade and 4 or 5 blunt robust setae on each merus; pereopods 4–7, ischium to carpus with tubercles along with inferior margins; and pleotelson with 1 pair of 2 depressions on proximal region.

Description of holotype male. Body (Fig. 1A, B), 2.1 times longer than width, oval, dorsoventrally depressed; dorsal surface smooth. Cephalon (Fig. 1C, D) triangular; posterior margin slightly tri-sinuated, but not distinct; rostrum truncated apically, stepped laterally; eyes large, separated each other. Pereonites, pereonite 1 slightly longer than other pereonites; pereonite 3 widest; pereonite 7 narrower than preceding pereonites, tapering posteriorly. Coxal plates visible on dorsal side, acute posteriorly; coxal furrows present in coxal plates 4–7. Pleonites, pleonite 1 hidden by pereonite 7, slightly visible on both lateral sides; pleonites 2–4 with subacute apex, but pleonite 5 with blunt apex. Pleotelson (Fig. 1E) semicircle or shield-shaped, tapering posteriorly; lateral margins concave proximally; dorsal surface with 1 pair of 2 depressions proximally and ~~a~~ medial carina; apex with numerous plumose and robust setae.

Antennule (Fig. 1F) reaching anterior margin of pereonite 1; peduncular article 1 wider than article 2, with 2 penicillate setae distally; article 2 subequal to article 1 in length, with 3 penicillate setae and 1 simple seta laterally; article 3 elongated oblong, longest, 1.7 times longer than article 2, with 1 penicillate seta and 2 short simple setae distally; flagellar article 1 rectangular, 0.3 times as long as peduncular article 3, without setae; articles 2–5 square, with 2 aesthetascs distally; article 6 minute, with 2 aesthetascs, 1 penicillate seta, and 3 simple setae. Antenna (Fig. 1G) exceeding beyond posterior margin of pereonite 1; peduncular article 1 globular; article 2 short, with 3 simple setae distally; article 3 4.7 times longer than article 2, with 1 simple seta distally; article 4 oblong, 1.5 times longer than article 3, with 1 simple seta; article

Comment [K17]: Male? Why not female?

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5 elongated, longest, 1.3 times longer than article 4, with 3 penicillate setae and 3 simple setae distally; flagellum consisting of 16 articles; each article with short simple setae distally except for first article without setae.

Frontal lamina (Fig. 1D) short, subacute distally; labrum projecting downwardly. Mandible (Fig. 1H–J), incisor acute, with 1 process covered by minute spinous papulae; molar process rounded; palp article 2 longer than others, with 10 serrated setae and 2 long simple setae along with lateral margin; article 3 with 17 serrate setae (bifurcated distally) laterally. Maxillule (Fig. 1K, L) slender, 4 robust setae distally; apex acute. Maxilla (Fig. 4M, N) stout proximally; inner lobe with 1 curved robust seta distally and 2 protrusions laterally; outer lobe with 2 curved robust setae. Maxilliped (Fig. 1O, P), first article oblong, 2.6 times longer than width, wider posteriorly; second article 0.3 times as long as first article, with 1 curved robust seta and long simple seta distally; third article 0.6 times longer than second article, with 4 curved robust setae and 1 simple seta distally.

Pereopods 1–3 (Fig. 2A–E), basis oblong, with 1–4 penicillate setae on superior margin and 1 simple seta at inferodistal angle; ischium almost 0.5 times as long as basis, expanding superior distal end, with 1 or 2 robust setae superodistally; merus trapezoidal, with several robust and simple setae at superodistal angle and 4 blunt robust setae along with inferior margin, but pereopod 2 with 5 blunt robust setae; carpus shortest, about 0.3 times as long as merus, with 1 robust seta on inferodistal end; propodus almost 3 times longer than carpus, with blade on palm; propodal blade 0.7 times as long as wide, with 8 robust setae distally and 1 long simple seta proximally; robust setae with 1 simple setule distally; dactylus curved, as long as propodus, without setae. Pereopods 4–7 (Fig. 2F–I), articles sequentially shortened; basis with 3–6 penicillate setae superiorly and 2 robust setae inferodistally, longest; ischium to carpus with tubercles and robust setae along with inferior margins, and robust setae at superior distal angles; propodus with several tubercles and robust setae along with inferior margin, and 1 penicillate seta and several simple setae at superior distal angle; dactylus slightly curved, without setae.

Pleopods (Fig. 3A–E) sequentially larger posteriorly; pleopods 2–4 with globular patterns along with lateral margins of exopods. Pleopod 1 (Fig. 3A), protopod with 6 coupling hooks and 3 plumose setae on medial margin and 3 simple setae on lateral margin; rami with plumose setae; exopods slightly longer than endopod. Pleopod 2 (Fig. 3B), protopod rectangular, with 5 coupling hooks and 8 plumose setae medially, 1 robust seta and 4 simple setae laterally; endopod

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smaller than exopod; appendix masculina inserted proximally, expanding distal end of endopod, but not reaching. Pleopods 3 and 4 (Fig. 3C, D), protopod with coupling hooks and plumose setae on medial margin and plumose setae on lateral margin; endopod much smaller than exopod, without plumose setae; exopod with plumose setae and patch; partial suture present on lateral margin. Pleopod 5 (Fig. 3E) subequal to pleopods 3 and 4, but endopod enlarged beyond protopod and without coupling hooks and plumose setae on medial margin.

Uropod (Figs. 1A, B, 3F), reaching distal end of pleotelson; protopod expanding distally on medial margin, 1 robust seta and 8 simple setae on lateral margin; rami elongated oval, with numerous plumose and robust setae; endopod longer than exopod; apexes rounded.

Remarks. The material of *R. excavata* **sp. nov.** can ~~be~~ easily be characterized as new to science by the following combinations of characters: (1) the rostrum is truncated distally and stepped laterally; (2) eyes are separated from each other; (3) pereopods 1–3 have eight robust setae on propodal blade and four or five blunt robust setae on each merus; (4) ischium to carpus in pereopods 4–7 have tubercles along with posterior margins; and (5) one pair of two depression are located at the proximal region of pleotelson.

Among the known 41 species of the genus *Rocinela*, only three species have separated eyes and more than seven robust setae on the propodal blade in pereopods 1–3: *Rocinela niponia* Richardson, 1909; *R. garricki* Hurley, 1957; and *R. pakari* Bruce, 2009 (*Richardson, 1909*; *Bruce, 2009*). Among them, *Rocinela excavata* **sp. nov.** most resembles *R. garricki* by sharing characteristics of the rostrum and propodal blade of perepopods 1–3. However, the former can be rapidly distinguished from the latter in terms of the distal end of the rostrum (truncated in the former vs. rounded in the latter) and the shape of the robust setae on the merus in pereopods 1–3 (blunt in the former vs. subacute in the latter).

Among seven species reported from the Far East, *Rocinela excavata* **sp. nov.** is most similar to *R. japonica* in the structure of rostrum and setal armature of pereopods 1–3's merus, while the latter exhibits a distinct difference in the number of setae on the propodal blade in pereopods 1–3 (eight setae in the new species vs. three or four robust setae in *R. japonica*) (*Richardson, 1898, 1904, 1909*; *Kussakin, 1974*; *Vasina, 1993*).

Etymology. The specific name, *excavata*, originates from the combination of Latin prefix *ex-* meaning "out of" and Latin word *cavatus* meaning "hollow out". It refers to the shape of the rostrum laterally excavated; gender feminine.

Family Gnathiidae Leach, 1814

Genus *Gnathia* Leach, 1814

Gnathia obtusispina sp. nov.

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Figures 4–6

Type material.—Holotype, designated here**:** South Korea: ♂, 3.2 mm, Hongdo-ri (34°43´22.8″N, 125°11´59.5″E), Heuksan-myeon, Sinan-gun, Jeollanam-do, 20 June 2018, 10 m, S.H Kim, leg., SCUBA diving, ZCIVIV0000001420. Paratypes: 2♂♂, same location as holotype, NIBRIV0000862802.

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Diagnosis. Body covered with long setae; cephalon with remarkable protuberances nearby eyes, medially concave on frontal border, bearing 2 inferior frontolateral processes ventrally; supraocular lobes prominent and projecting upwards; dentate blade of mandible irregularly present; pereonite 1 not fused to cephalon dorsally; and pleotelson rounded distally.

Description of holotype male. Body (Fig. 4A) 2.3 times longer than greatest width, with numerous long setae dorsally. Cephalon (Fig. 4B, C) oval to oblong, 0.4 times as long as wide, covered with numerous tubercles, with 1 pair of tooth-like blunt protuberances (arrowheads in Fig. 4B, C) near both eyes; dorsal sulcus narrow, U-shaped, positioned at median area anteriorly; frontal border medially concave, with 1 pair of 2 inferior frontolateral processes; frontal concavity shallow and narrow; supraocular lobes prominent, projecting upwards, with dentate apex; eyes located on lateral margins. Pereonites 1–4 covered with tubercles, whereas 4–7 without tubercles; pereonite 1 not fused to cephalon dorsally, immersed in posterior margin of cephalon; pereonites 2–4 subequal in length and width; pereonite 5 widest; pereonite 6 with concave posterior margin. *Pleonites*, epimera of pleonites 3–5 prominent. Pleotelson (Figs 4A, 6F) triangular; lateral margins convex, with several simple setae on distal end; apex rounded; proximal dorsal side with 2 pairs of simple setae and 1 pair of plumose setae.

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Antennule (Fig. 4F), peduncular article 1 ovoid to oblong, with 2 penicillate setae laterally; article 2 square, 0.7 times longer than article 1, with 4 penicillate setae and 3 simple setae distally; article 3 elongate and rectangular, 1.5 times longer than article 2, with 5 simple setae distally; flagellar article 1 shortest, 0.1 times as long as peduncular article 3, with 3 penicillate setae laterally; article 2 elongated oblong, 4.9 times longer than article 1, with 1 simple seta and 1 aesthetasc distally; article 3 oblong, 0.3 times as long as article 2, with 1 aesthetasc distally; article 4 subequal to article 3 in length, with 3 simple setae and 1 aesthetasc distally. Antenna (Fig. 4G) peduncular article 1 globular; article 2 square, 0.8 times as long as article 1; article 3 oblong, 1.9 times longer than article 2, with 2 penicillate setae and 7 simple setae distally; article 4 elongated rectangular, 1.3 times longer than article 3, with 3 penicillate setae and 6 simple setae distally; flagellum composed of 5 articles; each article square to oblong, similar each other in length, with simple setae distally.

Mandibles (Fig. 4A–E) pliers-shaped, half length of cephalon, elevated distally, with dorsal and internal lobes; dentate blade irregular; basal neck indistinct. Maxilliped (Fig. 4H), endite reaching proximal region of palp article 2; palp articles globular, similar to each other in shape, with plumose setae laterally; article 1 with 2 short simple setae distally; article 2 largest. Pylopod (Fig. 4I), article 1 longest, nearly occupying 70% of total length of pylopod, with numerous plumose setae on lateral margin, and 1 penicillate seta, 1 plumose seta, and 12 simple setae on medioventral side; article 2 ovoid, 0.2 times as long as article 1, with 2 short simple setae distally; article 1 elliptical, 0.3 times as long as article 2, with 1 simple seta on distal end.

Pereopod 2 (Fig. 5A) with tubercles in ischium to propodus inferiorly; basis with 3 penicillate setae superiorly, numerous simple setae superiorly and inferiorly; ischium 0.8 times as long as basis, with 1 serrate seta and 6 simple setae inferiorly, and 1 penicillate seta and 4 simple setae superiorly; merus 0.3 times as long as ischium, with 1 serrate seta and 3 simple setae inferiorly, and 3 simple setae superiorly; carpus similar to merus in length, with 1 simple seta and 2 serrate setae inferiorly; propodus oblong, 1.8 times longer than carpus, with 2 robust simple setae, 1 simple seta and several short simple setae on inferior margin, and 1 penicillate seta and 1 short simple seta at superodistal angle; dactylus rectangular, with 4 simple setae and 1 claw distally. Pereopods 3–6 (Fig. 5B–E) almost similar to pereopod 2; basis with tubercles superiorly except for pereopod 5.

Pleopods (Fig. 6A–E) similar to each other; protopod ovoid to oblong, with 1 simple seta laterally, 2 coupling hooks medially, rami elongated ovoid, with rounded apex; exopod of pleopod 2 with 1 penicillate seta distally; rami without plumose setae distally, while pleopods 3 and 5 with plumose setae distally; pleopod 2 with penicillate seta distally; appendix masculina not observed in pleopod 2.

Uropod (Fig. 6F), protopod rectangular, with 1 simple dorsal seta; rami with long simple setae distally; endopod slightly longer than exopod, with 6 penicillate setae and 3 simple setae dorsally.

Remarks. There are nine species characterized by the presence of tubercles on the cephalon and pereonites among 25 *Gnathia* species reported from the Far East: *G. tuberculata* Richardson, 1909 from the Nanao, Japan; *G. derzhavini* Gurjanova, 1933 from the Askold Island, Russia; *G. schmidti* Gurjanova, 1933 from the Bay of Vladimir, Russia; *G. teruyukiae* Ota, 2011 from the Ishigaki Island, Japan; *G. rufescens* Ota, 2015 from the Okinawa Island Japan; *G. albipalpebrata* Ota, 2014 from the Okinawa-jima Island, Japan; *G. parvirostata* Ota, 2014 from the Ishigaki Island, Japan; *G. nubila* Ota & Hirose, 2009 from the Okinawa Island, Japan; and *G. dejimagi* Ota, 2014 from the Okinawa-jima Island, Japan (*Boyko et al., 2008*; Song *& Min, 2018*; *Shodipo et al., 2021*). Although *G. obtusispina* **sp. nov.** also represents this character state, this new species is easily distinguishable from the latter species by the combination of the following character states: (1) the body is covered with long setae; (2) the cephalon has a pair of remarkable tooth-like blunt spinous protuberances nearby the eyes; (3) the frontal border of the cephalon is medially concave; (4) two inferior frontolateral processes are present ventrally; (5) the supraocular lobe is prominent and projecting upwards; (6) the dentate blade of the mandible is present and irregular; (7) pereonite 1 is not fused with cephalon dorsally and conspicuous; and (8) the apex of the pleotelson is rounded (*Richardson, 1909*; *Gurjanova, 1933*; *Ota, 2011, 2015*; *Ota & Hirose, 2009*).

Among tubercular gnathids, *G. obtusispina* **sp. nov.** is most close to *G. tuberculata* by having inferior frontolateral processes, prominent supraocular, and mandible as long as half-length of the cephalon. However, the former differs from the latter in terms of the medially concave frontal border of the cephalon (vs. produced in the latter), presence of a tooth-like blunt spinous protuberances on the cephalon near both eyes (vs. absent in the latter), number of inferior frontolateral processes (two in the former vs. four in the latter), and rounded apex of the pleotelson (vs. acute in the latter) (*Richardson, 1909*).

Etymology. The specific name, *obtusispina*, originates from the combination of Latin words *obtusus*, meaning “blunt” and *spina*, meaning “thorn”. This name refers to tooth-like blunt spinous protuberances on the cephalon near both eyes; gender feminine.

DISCUSSION

The genus *Rocinela* is distributed worldwide. It particularly shows high-latitude diversity (*Bruce, 2009*). Indeed, based on marine ecoregions of the world by *Spalding et al. (2007)*, 29 of 41 known *Rocinela* species have been reported from a temperate region (Table 1). Concerning biogeographic realms, 25 of 41 known species are recorded from the Pacific, especially 15 species from the western Pacific region, including seven species from the Far East. This means that the majority of *Rocinela* species have been described from the temperate western Pacific, so the region could be considered as diversity hotspot for the genus *Rocinela*. Based on personal observation, however, *Bruce (2009)* has mentioned that a significant number of undescribed species from the tropical western Pacific region is held at the Muséum national d'Histoire naturelle in Paris. The lack of taxonomists and concerns on the *Rocinela* species negatively might have affected our knowledge of the species diversity. Undescribed species can be discovered through further study in the trophic region. While among 29 known species from temperate region, only two species, *R. angustata* Richardson, 1904 and *R. belliceps* (*Simpson, 1864*), show a broad distribution ranging from the Northwest to Northeast Pacific despite most *Rocinela* species have endemic distribution ranges (*Richardson, 1904, 1905, 1909*; *Kussakin, 1979*; *Brusca & France, 1992*). Considering that host-association times is correlated with the distribution range and that *Rocinela* species can attach to the host temporally, these endemic distribution ranges of *Rocinela* species might be due to their feeding strategy with temporary ectoparasites attaching to fishes in their particular life history (*Bruce, 2009*; *Svavarsson & Bruce, 2012*; *Smit et al., 2019*). Although hosts of *R. angustata* and *R. belliceps* remain unknown, broad distribution ranges of these two species could be related to their host's distribution patterns (*Smit et al., 2019*).

Fifty-six and 76 species of 133 known *Gnathia* species have been reported from a temperate region and tropical region, respectively (Table 2; *Song & Min, 2018*; *Shodipo et al., 2021*). Only two species, *G. fragilis* Schultz, 1977 and *G. tuberculosa* (Beddard, 1886), are from the Southern Ocean, Antarctic (*Monod, 1926*; *Schultz, 1977*). According to the marine ecoregions of the world, the Central Indo-Pacific for 47 species is thought to be the most diverse hotspot of *Gnathia* (*Shodipo et al., 2021*). After the Central Indo-Pacific, the second-most rich species of 18 species have been reported from the temperate Northern Pacific that includes the study area of the

Comment [K25]: No need to mention many times in a paper.

present study. Consequently, the temperate Northern Pacific is considered to be the second most diverse hotspot following the Central Indo-Pacific. Within the temperate Northern Pacific, the Far East, from which 11 *Gnathia* species are recorded, could be regarded as a representative hotspot. While looking for substrate types from which *Gnathia* species are collected, most temperate species have been collected from soft substrates such as muddy, silt, and sandy flats in contrast to tropical *Gnathia* species reported from coral-reef habitats (*Cohen & Poore, 1994*; *Svavarsson & Bruce, 2012*). This is opposite to the general knowledge that gnathiid species prefer coral reef-associated habits (*Cohen & Poore, 1994*; *Santos & Sikkel, 2019*; *Smit et al., 2019*; *Svavarsson & Bruce,* 2012, 2019). Considering that the attribute of substratum strongly affects the distribution of gnathiids and that each species has a different habitat depending on its life history stages (*Smit et al., 2019*), the life history of *Gnathia* species could be differed depending on whether they live in a temperate or a tropic region (Santos & Sikkel, 2019). However, further study about the substratum preference between temperate and tropic *Gnathia* species is needed because most ecological studies of these species have been conducted from coral reef-associated habitats (*Grutter et al., 2000, 2018*; *Santos & Sikkel, 2019*; *Smit et al., 2019*; *Shodipo et al., 2021*). Additionally, despite most *Gnathia* species are known as endemic, two species, *G. calmani* Monod, 1926 and *G. nasuta* Nunomura, 1992, have wide distributions ranging from the tropic to the temperate region (*Monod, 1926*; *Holdish & Harrison, 1980*; *Nunomura, 1992*; *Ota, 2013*). Although two species, *G. grandilaris* Coetzee, Smit, Grutter & Davies, 2008 and *G. trimaculata* Coetzee, Smit, Grutter & Davies, 2009, have been reported only from the Central Indo-Pacific, they also show a wide geographical distribution ranging from Australia to Japan (*Coetzee et al., 2008, 2009*; *Ota & Hirose, 2009*). According to *Shodipo et al. (2021)*, the long-distance dispersal of some *Gnathia* species was facilitated by their host that had a wide movement radius in a short period of time (e.g. sharks). Considering wide movement radii of hosts such as sharks and ray in *G. grandilaris* and *G. trimaculata*, the two species showing wide distribution ranges, *G. calmani* and *G. nasuta*, also could be parasites of hosts having wide movement radii (*Coetzee et al., 2008, 2009*; *Shodipo et al., 2021*).

CONCLUSION

The present study of Korean ectoparasitic isopods revealed high species diversity of *Rocinela* and *Gnathia* species in the temperate Northern Pacific region by the discovery of two new species, *Rocinela excavata* **sp. nov.** and *Gnathia obtusispina* **sp. nov.** The two new species are the species records for the 16th *Rocinela* species and the 19th *Gnathia* species in this region, respectively. Our investigation on the geographical distributions of known *Rocinela* and *Gnathia* species told that the temperate Northern Pacific has the most *Rocinela* species and the second most *Gnathia* species in the regional species richness of each genus. It also showed that even if both genera indicate great diversity in the western Pacific, *Rocinela* species reveal high-latitude diversity while *Gnathia* species represent low-latitude diversity, particularly in the Central Indo-Pacific region.

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Competing Interests

The authors have no competing interests to disclose.

Author Contributions

- Sung Hoon Kim conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, and approved the final draft.
- Jong Guk Kim designed the experiments, analyzed the data, reviewed drafts of the paper, and approved the final draft.
- Seong Myeong Yoon conceived and designed the experiments, reviewed drafts of the paper, and approved the final draft.

Comment [K26]: Why?

Comment [K27]: rephrase

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Figure legends

Figure 1. *Rocinela excavata* sp. nov., holotype, female. (A) Habitus, dorsal view; (B) Habitus, lateral view; (C) Cephalon, dorsal view; (D) Distal end of cephalon, ventral view; (E) Distal end of pleotelson; (F) Antennule; (G) Antenna; (H) Mandible; (I) Serrate seta of mandibular palp; (J) mandibular incisor; (K) Maxillule; (L) Distal end of maxillule; (M) Maxilla; (N) Distal end of maxilla; (O) Maxilliped; (P) Distal end of maxilliped. Scale bars: A, B = 5 mm, C–E = 2 mm, F, G = 1 mm; H, K, M, O = 0.5 mm, N = 0.2 mm, L, P = 0.1 mm, I, J = 0.05 mm.

Figure 2. *Rocinela excavata* sp. nov., holotype, female. (A) Pereopod 1; (B) Propodal blade of pereopod 1; (C) Pereopod 2; (D) Robust seta of propodal bladed in pereopod 2; (E) Pereopod 3; (F) Pereopod 4; (G) Pereopod 5; (H) Pereopod 6; (I) Pereopod 7. Scale bars: A, C, E, F–I = 1 mm, B = 0.1 mm; D = 0.05 mm.

Figure 3. *Rocinela excavata* sp. nov., holotype, female. (A) Pleopod 1; (B) Pleopod 2; (C) Pleopod 3; (D) Pleopod 4; (E) Pleopod 5; (F) Uropod. Scale bar: A–F = 1 mm.

Comment [K28]: Male in description?

Figure 4. *Gnathia obtusispina* sp. nov., holotype, male. (A) Habitus, dorsal view; (B) Cephalon, dorsal view; (C) Cephalon, ventral view; (D) Cephalon, lateral view; (E) Mandible, lateral view; (F) Antennule; (G) Antenna; (H) Maxilliped; (I) Pylopod. Arrows indicate a tooth-like blunt spine. Scale bars: A = 1 mm, B–D = 0.5 mm, E–I = 0.2 mm.

Figure 5. *Gnathia obtusispina* sp. nov., holotype, male. (A) Pereopod 2; (B) Pereopod 3; (C) Pereopod 4, (D) Pereopod 5; (E) Pereopod 6. Scale bar: A–E = 0.2 mm.

Figure 6. *Gnathia obtusispina* sp. nov., holotype, male. (A) Pleopod 1; (B) Pleopod 2; (C) Pleopod 3; (D) Pleopod 4; (E) Pleopod 5; (F) Pleotelson and uropod. Scale bar: A–F = 0.5 mm.

Comment [K29]: Based on females only you need to describe the new species.

How?

Table legends

Table 1. Summary of *Rocinela* species from the temperate region.

Table 2. Summary of *Gnathia* species from the temperate region.