New Records of Species of Gebiidea and Anomura (Crustacea: Decapoda) from the Sea of Japan

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Six decapod crustacean species, including one gebiidean and five anomurans, are reported as new to the marine fauna in the Sea of Japan based on material collected from the coast of Tottori Prefecture, western Japan. Among them, the mud squat lobster *Paramunida tricarinata* (Alcock, 1894) is new to the Japanese fauna. In addition to the six species, the occurrence of the diogenid hermit crab *Paguristes versus* Komai, 2001 in the Sea of Japan is confirmed on the basis of specimens newly obtained from Tottori Prefecture. The current knowledge on the fauna of Gebiidea and Anomura in the western Japanese coast of the Sea of Japan is also briefly summarized.

Key Words: Mud shrimp, hermit crab, squat lobster, fauna, biogeography, San'in area, East Asia.

Introduction

The Sea of Japan is the marginal, semiclosed sea surrounded by the Eurasian Continent, Sakhalin, and two Japanese main islands (Hokkaido and Honshu). It is connected to the Pacific Ocean by five shallow straits from the north to south: Strait of Tartary (=Mamiya Strait), La Pérouse Strait (=Soya Strait), Tsugaru Strait, Kanmon Straits, and Tsushima Strait (Fig. 1A). The Tsushima Current brings warmer and more saline water to the north along the coast of Honshu, merges into the Tsugaru Current, and primary flows into the Pacific Ocean through the Tsugaru Strait. This encourages the warm marine fauna in its richness and that the distribution of tropical water species particularly in the western area as the “inflow gate” to the Sea of Japan for the Tsushima Current. The western area “San'in” is composed of the marine coasts of five Japanese prefectures from the west to east: Yamaguchi, Shimane, Tottori, Hyogo, and Kyoto (Fig. 1B). Nishimura (1992) discussed on seven zoogeographical (zooclimatic) zones categorized in Japanese waters (tropical, subtropical, warm temperate, moderate temperate, cool temperate, subboreal, and boreal zones) and suggested the area around Shimane Prefecture to be a boundary between the warm temperate and moderate temperate zones in the coast of the Sea of Japan. In “San'in” area, the fauna of decapod crustaceans in Shimane and Tottori Prefectures is relatively well compiled by recent studies (*cf.* Takeda *et al.* 2011, for Brachyura; Osawa *et al.* 2014b, 2015, 2016, 2018, for Anomura), but their inventory is still incomplete.

The second author has collected marine invertebrate specimens in order to understand the coastal fauna of Tottori Prefecture (Fig. 1C). The present paper reports on one gebiidean [*Austinopecten narutensis* (Sakai, 1986)] and five

anomuran species [*Paguristes gonagrus* (H. Milne Edwards, 1836) (Diogenidae); *Nematopagurus australis* (Henderson, 1888) (Paguridae); *Galathea guttata* Osawa, 2004 (Galatheididae); *Munida agave* Macpherson and Baba, 1993, and *Paramunida tricarinata* (Alcock, 1894) (Munididae)] as new additions to the decapod crustacean fauna in the Sea of Japan, with a brief summary of the current knowledge on the fauna of Gebiidea and Anomura in the western Japanese coast of the Sea of Japan. This study only contains a finding of a single species (*Paramunida tricarinata*) new to the entire fauna of Japanese waters and gives some new information on the local fauna. However, we believe it is valuable to supplement rather little knowledge on the marine invertebrate fauna in the coast of the Sea of Japan, for further succeeding studies.

Materials and Methods

The collection localities of the present specimens are shown in Fig. 1C. The specimens examined were collected by using SCUBA (depths of 10–26 m) and beam trawls (depths of 50–120 m), except those of *Austinopecten narutensis* which lack the data of the collection method and depth. The approximate latitude and longitude are given for the collection localities of the specimens. Specimen size is indicated as following: for Upogebiidae (mud shrimps), the carapace length (cl, in mm), measured from the tip of the rostrum to the midpoint of the posterodorsal margin of the carapace; for Diogenidae and Paguridae (hermit crabs), the shield length (sl), from the tip of the rostrum to the midpoint of the posterior margin of the shield; and for Galatheididae and Munididae (squat lobsters), the postorbital carapace length (pcl), along the dorsal midline from the posterior margin of the orbit to the posterior margin of the carapace.

Fig. 1. Maps of studied region. A, Japanese main islands and their adjacent areas, showing the Sea of Japan and “San’in” area, western Japanese coast of the sea; B, “San’in” area composed of five Japanese prefectures (Yamaguchi, Shimane, Tottori, Hyogo, and Kyoto); C, localities in Tottori Prefecture (Sakaiminato, Nagaobana, and Tajiri) from which the present specimens were collected.

All the material is deposited in the collection of the Tottori Prefectural Museum, Tottori (TRPM).

In this study, according to Motoh (2007), the Japanese area of the Sea of Japan is defined as coasts and off-shores from Yamaguchi Prefecture (Kammon Straits) to Hokkaido Prefecture (Soya Strait).

Systematic Account

Infraorder **Gebiidea** de Saint Laurent, 1979

Family **Upogebiidae** Borradaile, 1903

Austinogebina narutensis (Sakai, 1986)

(Fig. 2A–D)

Upogebia major (non De Haan, 1841): Miyake 1982: pl. 31, fig. 5.

Upogebia spinifrons non Haswell, 1881: Sakai 1984: 209, figs 1–3.

Upogebia narutensis Sakai, 1986: 25, pl. 1 (type locality: Ohge-Jima, Naruro, Tokushima Prefecture, Japan; low intertidal); Ngoc-Ho 1994: 198, figs 4, 5 (in part); Sakai 2006: 130.

Austinogebina narutensis: Ngoc-Ho 2001: 50, fig. 3; Sato *et al.* 2016: 36, fig. 5A.

Material examined. Tottori Prefecture. Off Sakaiminato (35°52'N, 133°31'E), 16 October 2006, coll. M. Nagata, 1 male (cl 17.9 mm), 3 females (cl 16.7–18.9 mm), TRPM-780.

Distribution. Japan and Taiwan; lower intertidal to depths of 5–30 m (Sakai 2006, as *Upogebia narutensis*). Japanese records include Ibaraki, Shizuoka, Wakayama, Hiroshima, Tottori, Yamaguchi (Honshu mainland), Tokushima, Kochi (Shikoku mainland), and Kagoshima (Kyushu mainland) Prefectures (Itani 2004; Sakai 2006; Sato *et al.* 2016; present study). The present specimens reveal the first record of this species from the Sea of Japan.

Habitat. Seashore, sand or muddy sand (Itani 2004). In the Seto Inland Sea, *Austinogebina narutensis* is sympatric with *Upogebia issaeffi* (Balss, 1913) on sandy shores and with *U. major* (De Haan, 1841) on a muddy shore (Itani 2004); whereas in Kashima-nada, Ibaraki Prefecture, *A. narutensis* inhabits subtidal fine-sand bottom in open coast (Sato *et al.* 2016). The structure of burrows of *A. narutensis* was studied in detail by Kinoshita and Itani (2005).

Remarks. The genus *Austinogebina* Ngoc-Ho, 2001 now includes eight species (*cf.* Liu and Sha 2015) and among them, only *A. narutensis* and *A. wuhsienweni* (Yu, 1931) have been recorded from Japanese waters (Sakai 2006). *Austinogebina narutensis* is characterized by the rostrum being 1.2–1.5 times as long as broad at the base, the anterior half of the rostrum being unarmed dorsally, the third article of the antennal peduncle with a distal spine on the lower margin, and the merus of the second pereopod with a distal spine on the upper margin (Ngoc-Ho 2001). This species has been recorded from the southwestern coast of Kyushu (Izumi, Kagoshima Prefecture; Sakai 2006). The present record of *A. narutensis* in the Sea of Japan suggests that the

Fig. 2. Preserved specimens. A, *Austinogebia narutensis* (Sakai, 1986), female (cl 18.9 mm), TRPM-780, left lateral view; B, same, carapace, dorsal view; C, same, left lateral view, anterior part of body, showing pereopod 1; D, *Austinogebia narutensis* (Sakai, 1986), male (cl 17.9 mm), TRPM-780, left lateral view; E, *Paguristes gonagrus* (H. Milne Edwards, 1836), male (sl 6.4 mm), TRPM-782, dorsal view; F, *Paguristes versus* Komai, 2001, male (sl 5.8 mm), TRPM-783, dorsal view; G, *Nematopagurus australis* (Henderson, 1888), female (sl 4.3 mm), TRPM-784, dorsal view; H, *Galathea guttata* Osawa, 2004, male (pcl 3.1 mm), TRPM-785, dorsal view; I, *Munida agave* Macpherson and Baba, 1993, ovigerous female (pcl 7.4 mm), TRPM-788, dorsal view.

species is also distributed in the northwestern coast of Kyushu, although no records of the species from the area are available so far

Infraorder **Anomura** MacLeay, 1838
 Family **Diogenidae** Ortmann, 1892
Paguristes gonagrus (H. Milne Edwards, 1836)
 (Figs 2E, 3A)

Restricted synonymy.

Pagurus gonagrus H. Milne Edwards, 1836: 281 (type locality: China Sea).

Paguristes gonagrus: Alcock 1905: 155 (list); Rahayu and Forest 2009: 1312, figs 1, 2; Komai 2010: 10, figs 1–5 (compilation).

Paguristes balanophilus non Alcock, 1905: Miyake 1978: 40, text-fig. 14, pl. 2, fig. 7; Miyake 1982: 97, pl. 33, fig. 1; Minemizu 2000: 131, unnumbered fig.

Material examined. **Tottori Prefecture.** Off Nagaobana (35°55'N, 134°00'E), Tottori: 50 m, beam trawl, 13 July 2018, coll. Y. Ota, 1 male (sl 5.6 mm), TRPM-781; 50 m, beam trawl, 20 August 2018, coll. Y. Ota, 1 male (sl 6.4 mm), TRPM-782.

Distribution. Japan, Taiwan, China Sea, Bohol in the Philippines; depths of 13–200 m (Komai 2010). Japanese records include the Pacific coast from Sagami Bay to the Ryukyu Islands, and Tottori Prefecture on the coast of the Sea of Japan (Komai 2010; present study). The present specimens reveal the first record of this species from the Sea of Japan.

Habitat. Muddy sand; found in various species of gastropod shells, which are always encrusted with *Epizoanthus* Gray, 1867 (Cnidaria: Anthozoa: Zoantharia: Epizoanthidae) (Minemizu 2000; Komai 2010). The present specimens were collected from the bottom containing dead shells and gravels.

Remarks. *Paguristes gonagrus* has been confounded with *P. balanophilus* Alcock, 1905 in Japanese literature (cf. Miyake 1978, 1982). The true identities of the two species were clarified by the re-examinations of respective type specimens by Rahayu and McLaughlin (2006) and Rahayu and Forest (2009) and a subsequent detailed description of *P. gonagrus* by Komai (2010). *Paguristes gonagrus* is distinctive among Japanese congeners and practically distinguished by the dense covering of long soft setae on the dorsal surface of each chela, which obscure or conceal the armature, and the lateral surfaces of the meri of the chelipeds and ambulatory legs each with a small red spot distally, which is circumscribed by a broad violet ring (cf. Komai 2010).

Paguristes versus Komai, 2001
 (Figs 2F, 3B)

Restricted synonymy.

Paguristes kagoshimensis non Ortmann, 1892 (= *Paguristes digitalis* Stimpson, 1858): Kim 1973: 214, 597, fig. 44, pl. 69, fig. 25; Miyake 1978: 35, fig. 12; Miyake 1982: 96, pl.

32, fig. 5.

Paguristes versus Komai, 2001: 406, figs 23–27 (type locality: Okinoyama Bank, Sagami-nada, Japan, 34°59'N, 139°39'E; 105–113 m); McLaughlin *et al.* 2007: 54, 2 unnumbered figs.

Material examined. **Tottori Prefecture.** Off Nagaobana (35°55'N, 134°00'E), Tottori, 100 m, beam trawl, 15 May 2018, coll. Y. Ota, 3 males (sl 4.9–5.8 mm), TRPM-783.

Distribution. Japan, Korea, Taiwan; 80–221 m, possibly to 254 m (Komai 2001; McLaughlin *et al.* 2007). Japanese records include the Pacific coast from Boso Peninsula to the Ohsumi Islands, northern Ryukyu Islands (Komai 2001), and Toyama and Tottori Prefectures on the coast of the Sea of Japan (Kikuchi 1932, as *P. kagoshimensis* Ortmann, 1892; present study).

Habitat. No previous records on the collection substrate, but sampling gears mentioned in the previous literature (e.g., Komai 2001; McLaughlin *et al.* 2007) suggest that specimens of *P. versus* were collected from soft bottoms. The present specimens were collected from the muddy sand substrate.

Remarks. This species had been referred to as *Paguristes kagoshimensis* in previous literature (cf. Miyake 1978, 1982). With the reexamination of the type material of *P. kagoshimensis*, Komai (2001) clarified that *P. kagoshimensis* was actually conspecific with *P. digitalis* Stimpson, 1858, and assigned the taxon confounded with *P. kagoshimensis* to his new species *P. versus*. The occurrence of *P. versus* from the Sea of Japan has been confirmed by the present specimens, although Kikuchi (1932) had recorded “*P. kagoshimensis*” from Toyama Bay in the area.

Four species of the genus *Paguristes* Dana, 1851 are now known from the Sea of Japan with the addition of the two species recorded in this paper: *P. digitalis*, *P. gonagrus*, *P. ortmanni* Miyake, 1978, and *P. versus* (cf. Motoh 2007; present study). Two species of the allied genus *Areopaguristes* Rahayu and McLaughlin, 2010, *A. hirsutimanus* (Kobjakova, 1971) (junior synonym: *Stratiotes nigroapiculus* Komai, 2009) and *A. japonicus* (Miyake, 1961), are also known from the Sea of Japan (Motoh 2007, as *Paguristes*; Komai 2009, as *Stratiotes* Thomson, 1899; Marin 2016).

Family **Paguridae** Latreille, 1802
Nematopagurus australis (Henderson, 1888)
 (Figs 2G, 3C)

Restricted synonymy.

Catapagurus australis Henderson, 1888: 76, pl. 8, fig. 1 (type locality: Arafura Sea, *Challenger* stn 188, 09°59'S, 139°42'E; 51 m).

Nematopagurus australis: McLaughlin 1997: 505; McLaughlin 2004: 221, fig. 26; Komai and Takeda 2006: 99; McLaughlin *et al.* 2007: 234, 2 unnumbered figs.

Nematopagurus cf. australis: McLaughlin 2002: 436, fig. 7F–H.

Material examined. **Tottori Prefecture.** Off Nagaobana

Fig. 3. Fresh specimens. A, *Paguristes gonagrus* (H. Milne Edwards, 1836), male (sl 6.4 mm), TRPM-782, dorsal view; B, *Paguristes versus* Komai, 2001, male (sl 5.8 mm), TRPM-783, right lateral view; C, *Nematopagurus australis* (Henderson, 1888), female (sl 4.3 mm), TRPM-784, dorsal view; D, *Munida agave* Macpherson and Baba, 1993, ovigerous female (pcl 7.5 mm), TRPM-787, dorsal view; E, *Munida pherusa* Macpherson and Baba, 1993, ovigerous female (pcl 7.7 mm), TRPM-802, dorsal view; F, *Munida pherusa* Macpherson and Baba, 1993, male (pcl 6.6 mm), TRPM-802, dorsal view; G, *Paramunida tricarinata* (Alcock, 1894), ovigerous female (pcl 7.9 mm), TRPM-790; H, *Pagurus nipponensis* (Yokoya, 1933), ovigerous female (sl 5.9 mm), TRPM-798; I, *Bathymunida brevirostris* (Yokoya, 1933), female (pcl 5.4 mm), TRPM-801.

(35°55'N, 134°00'E), Tottori, 100 m, beam trawl, 15 May 2018, coll. Y. Ota, 1 female (sl 4.3 mm), TRPM-784.

Distribution. Japan, Taiwan, South China Sea, Malaysia, Indonesia, New Caledonia, and Fiji; subtidal to 292 m, possibly to 417 m (McLaughlin 2004). Japanese records include Suruga and Sagami Bays and Tottori Prefecture in Honshu mainland (McLaughlin 2004; Komai and Takeda 2006; present study). The present specimen reveals the first record of this species from the Sea of Japan.

Habitat. Syntypes collected from green mud substrate and reef (McLaughlin 2004). The present specimen was collected from the muddy sand substrate.

Remarks. Although the right cheliped of the present specimen is missing, there is no doubt on the species identification because the specimen has other characters diagnostic to *N. australis* such as the left chela unarmed or with a median row of small spines on the dorsal surface, the dactylus of the left cheliped with a row of spines on the dorsomesial margin; and the dactylus of the left third pereopod being more than 1.5 length of the propodus, prominently curved ventrally and twisted, and with ventral marginal spines not clearly visible in lateral view (cf. McLaughlin 2004; McLaughlin *et al.* 2007).

Family **Galatheidae** Samouelle, 1819

Galathea guttata Osawa, 2004

(Fig. 2H)

Galathea sp. B: Kato and Okuno 2001: 88, unnumbered fig. *Galathea guttata* Osawa, 2004: 93, figs 1, 2, 3A, B (type locality: Kume Island, Ryukyu Islands, Japan; 18 m); Baba *et al.* 2008: 69; Dong and Li 2010: 11, fig. 6; Macpherson and Robainas-Barcia 2015: 133.

Material examined. Tottori Prefecture. Off Tajiri, Iwami (35°59.1'N, 134°31.0'E), 12 m, SCUBA, 11 October 2017, coll. Y. Ota, 1 male (pcl 3.1 mm), TRPM-785.

Distribution. Japan, South China Sea, Papua New Guinea, and New Caledonia; depths of 1–54 m (Macpherson and Robainas-Barcia 2015). Japanese records include the Ryukyu Islands (Okinawa and Kume Islands), Izu Islands (Hachijo Island), and Tottori Prefecture (Kato and Okuno 2001, as *Galathea* sp. B; Osawa 2004; present study). The present specimen reveals the occurrence of this species in the Sea of Japan for the first time.

Habitat. Rock; dead and living coral; and coarse mud, sand and shell (Osawa 2004; Dong and Li 2010). The present specimen was collected from the underside of a rock.

Remarks. This galatheid can be regarded as a tropical shallow-water species, estimated from the known distribution. The uninterrupted mesogastric ridge between the first branchial marginal spines on the carapace and two rounded white spots at the base of the cheliped fingers are diagnostic for *G. guttata*, and these characters immediately distinguish the species from other local congeners such as *G. orientalis* Stimpson, 1858 and *G. peitho* Macpherson and Robainas-Barcia, 2015, known from Tottori and/or Shimane Prefectures (cf. Osawa *et al.* 2014b, 2015, 2018).

Family **Munididae** Ah Yong, Baba, Macpherson, and Poore, 2010

Munida agave Macpherson and Baba, 1993

(Figs 2I, 3D)

Munida agave Macpherson and Baba, 1993: 387, figs 1, 2 (type locality: Philippines, MUSORTOM 2 stn 33, 13°32.3'N, 121°07.5'E; 130–137 m.); Macpherson 1997: 603; Baba 2005: 89, 258; Baba *et al.* 2008: 84 (compilation).

Material examined. Tottori Prefecture. Off Nagaobana (35°55'N, 134°00'E), Tottori: 100 m, beam trawl, 15 May 2018, coll. Y. Ota, 2 males (pcl 5.9, 6.0 mm), TRPM-786; 70 m, beam trawl, 13 July 2018, coll. Y. Ota, 1 ovigerous female (pcl 7.5 mm), TRPM-787; 100 m, beam trawl, 13 July 2018, coll. Y. Ota, 1 ovigerous female (pcl 7.4 mm), TRPM-788; 70 m, beam trawl, 17 April 2019, coll. Y. Ota, 1 female (pcl 5.3 mm), TRPM-789.

Distribution. Japan, the Philippines, and Indonesia; depths of 89–549 m (Baba *et al.* 2008). Japanese records include Sagami Bay, and Tottori and Kagoshima Prefectures (Macpherson and Baba 1993; Baba 2005; present study). The present specimens reveal the first record of this species from the Sea of Japan.

Habitat. Hard bottom, rock (Baba 2005). The present specimens were collected from the muddy sand substrate.

Remarks. The present specimens of *Munida agave* were found together with another congener, *M. pherusa* Macpherson and Baba, 1993, in the same trawl catch collected from off Nagaobana, at depths of 80–100 m. The latter species has been already recorded from the Sea of Japan, off Yamaguchi Prefecture (Komai *et al.* 2002). The two species are separated for each other by characters discussed by Macpherson and Baba (1993), as well as the fresh coloration. The bases of the rostrum and cheliped fingers have a white patch respectively in *M. pherusa* unlike in *M. agave* (Fig. 3D–F).

Paramunida tricarinata (Alcock, 1894)

[New standard Japanese name:

Mitsutoge-zarazara-chu-koshiori-ebi]

(Figs 3G, 4)

Restricted synonymy.

Munida tricarinata Alcock, 1894: 324 (type locality: Andaman Sea, 205 m); Alcock and Anderson 1895: pl. 12, fig. 1.

Paramunida scabra (non Henderson, 1885): Wu *et al.* 1998: 145, figs 41, 42G; Macpherson 1993: 462 (in part).

Paramunida tricarinata: Baba 2005: 304; Baba *et al.* 2008: 175 (list of occurrences); Baba *et al.* 2009: 283, figs 260, 261; Cabezas *et al.* 2010: 56, figs 15H, 18I; McCallum *et al.* 2016: 216, figs 2B, C, 8.

Material examined. Tottori Prefecture. Off Nagaobana (35°55'N, 134°00'E), Tottori: 100 m, beam trawl, 15 May 2018, coll. Y. Ota, 1 male (pcl 6.6 mm), 1 ovigerous female

Fig. 4. *Paramunida tricarinata* (Alcock, 1894), ovigerous female (pcl 7.9 mm), TRPM-790. A, carapace and abdomen, dorsal view; B, carapace, left lateral view (arrow showing third spine on midline of mesogastric region); C, spines on midline of mesogastric region, left lateral view; D, sternal plastron, ventral view; E, left eye, antennular article 1, and antennal peduncle, ventral view (setae omitted). Scale bars for C and E equal 1.0 mm.

(pcl 7.9 mm), TRPM-790; 100 m, beam trawl, 20 August 2018, coll. Y. Ota, 1 female (pcl 6.2 mm), 1 ovigerous female (pcl 5.5 mm), TRPM-791; 120 m, beam trawl, 20 August 2018, coll. Y. Ota, 1 female (pcl 6.3 mm), TRPM-792.

Distribution. Taiwan, Philippines, Andaman Sea, north-western Australia, Maldives Islands, and Arabian Sea; depths of 187–384 m (McCallum *et al.* 2016). Newly recorded from Japanese waters.

Habitat. No previous records on the collection substrate, but vast majority of the previous specimens were collected by trawl, suggesting that they were probably on soft bottoms. The present specimens were collected from muddy sand substrates.

Remarks. The present material from the Sea of Japan agrees well with Taiwan and Philippine specimens of *P. tricarinata* reported by Baba *et al.* (2009) and Cabezas *et al.* (2010) in the following diagnostic features (Fig. 3): the rostral spine is larger than the supraocular spines; the carapace has a row of three spines in the midline of the mesogastric region and tufts of long and dense setae along the anterior branch of the cervical groove; the sternal plastron has numerous striae; the anterior prolongation of the antennal article 1 is spiniform and does not have a row of spines on the dorsal margin; the antennal article 2 is slightly longer than broad, the distomesial spine is spiniform and slightly overreaches the end of the antennal peduncle at most (in

the present material, it reaches the end of the antennal peduncle), the distolateral spine never reaches the end of that article; and the antennal article 3 is slightly longer than broad. Unlike these specimens from Japan, Taiwan, and the Philippines, the antennal article 2 of the north-western Australian material reported by McCallum *et al.* (2016) has the distomesial spine extending far beyond the end of the antennal peduncle and the distolateral spine reaching or slightly exceeding the end of the article 3, although the Tamura-Nei genetic divergence using the mitochondrial ND1 and 16S rRNA genes between specimens of *P. tricarinata* from north-western Australia and Taiwan is lower than those between sister taxa (0.008 ± 0.004 vs. 0.018 ± 0.004 between *P. ascella* McCallum, Cabezas and Andreakis, 2016 and *P. tricarinata*; McCallum *et al.* 2016).

The size of the median spines in the mesogastric region of the carapace may vary in *P. tricarinata*. In the present material, the three spines on the mesogastric median row decrease in size posteriorly; the anterior two spines are strong and the third spine is smaller than the second or greatly reduced in size (Fig. 4B, C), as illustrated for a Philippine specimen by Cabezas *et al.* (2010: fig. 15H). In the illustrated specimens from Taiwan and north-western Australia (Baba *et al.* 2009: fig. 261a; McCallum *et al.* 2016: fig. 8A, B), the spines are subequal in size and the third spine is rather large. The anterior prolongation of the antennal article 1 is

also proportionally shorter in the present material than the previously reported specimens. In the material examined, it overreaches the distal margin of the antennular article 1 by one third (Fig. 4E), instead of about half of its length in other described/illustrated specimens (Cabezas *et al.* 2010: fig. 18I; McCallum *et al.* 2016: fig. 8D).

Although literature records of *P. tricarinata* include western Indian Ocean localities (Laurie 1926; Tirmizi 1966, as *Munida* Leach, 1820; Baba 1990; Macpherson 1993), identities of these specimens were questioned by Cabezas *et al.* (2010).

In Japanese waters, three congeneric species, *P. leptotes*

Macpherson and Baba, 2009 (Baba 1982, 1986; as *Munida proxima* Henderson, 1885), *P. scabra* (Henderson, 1885), *P. stichas* Macpherson, 1993, are known (*cf.* Baba 2005; Macpherson and Baba 2009). *Paramunida tricarinata* is the fourth species of the genus recorded from Japan.

Discussion

Current knowledge on the fauna of Gebiidea and Anomura in “San’in” area

Four gebiidean species are hitherto known from the Japa-

Table 1. First records of anomuran species from Tottori Prefecture, “San’in” area, western Japanese coast of the Sea of Japan.

Species	Voucher specimens	Previous Japanese records in the Sea of Japan
Diogenidae		
<i>Paguristes gonagrus</i> (H. Milne Edwards, 1836)	Off Nagaobana (35°55'N, 134°00'E), Tottori, 50 m, beam trawl, 20 August 2018, 1 male (sl 6.4 mm), TRPM-782 (Figs 2E, 3A).	No.
<i>Paguristes versus</i> Komai, 2001	Off Nagaobana, Tottori, 100 m, beam trawl, 15 May 2018, 1 male (sl 5.8 mm), TRPM-783 (Figs 2F, 3B).	Toyama Bay, Toyama Prefecture (Kikuchi 1932, as <i>P. kagoshimensis</i>).
Paguridae		
<i>Catapaguroides fragilis</i> (Melin, 1939)	Off Tajiri (“Yamadashi”, 35°60.2'N, 134°31.1'E), Iwami, 26 m, 4 June 2019, 1 ovigerous female (sl 1.2 mm), TRPM-793.	Oki Islands, Shimane Prefecture (Osawa <i>et al.</i> 2015).
<i>Nematopagurus australis</i> (Henderson, 1888)	Off Nagaobana, Tottori, 100 m, beam trawl, 15 May 2018, 1 female (sl 4.3 mm), TRPM-784 (Figs 2G, 3C).	No.
<i>Nematopagurus tricarinatus</i> (Stimpson, 1858)	Off Nagaobana, Tottori, 50 m, beam trawl, 13 July 2018, 1 male (sl 3.1 mm), TRPM-794.	Oki Islands, Shimane Prefecture (Osawa <i>et al.</i> 2015).
<i>Pagurus conformis</i> De Haan, 1849	Off Nagaobana, Tottori, 100 m, beam trawl, 15 May 2018, 1 male (sl 4.1 mm), TRPM-795.	North of Nagato, Yamaguchi Prefecture (Yokoya 1933, as <i>Eupagurus</i>).
<i>Pagurus constans</i> (Stimpson, 1858)	Off Nagaobana, Tottori, 70 m, beam trawl, 15 May 2018, 1 male (sl 9.5 mm), TRPM-796.	Kyoto, Ishikawa, Niigata, Yamagata, Akita, Aomori, and Hokkaido Prefectures (<i>cf.</i> Motoh 2007).
<i>Pagurus erythrogrammus</i> Komai, 2003	Off Tajiri (“Yamadashi”), Iwami, 26 m, 4 June 2019, 1 male (sl 1.8 mm), TRPM-797.	Izumo and Matsue, Shimane Prefecture (Osawa <i>et al.</i> 2014b); Wakasa Bay, Kyoto Prefecture (Asakura 2006); Echizen, Koshino, and Mikuni, Fukui Prefecture (Komai 2003)
<i>Pagurus nipponensis</i> (Yokoya, 1933)	Off Nagaobana, Tottori, 100 m, beam trawl, 17 April 2019, 1 ovigerous female (sl 5.9 mm), TRPM-798 (Fig. 3H).	Wakasa Bay, Kyoto Prefecture; Shonai-hama, Yamagata Prefecture (Asakura 2006); Tsugaru Strait, Aomori Prefecture (Yokoya 1933, as <i>Eupagurus</i>)
<i>Pagurus quinquelineatus</i> Komai, 2003	Off Haneo-misaki (“Goishiwara”, 35°60.4'N, 134°33.9'E), Iwami, 10 m, 13 August 2018, 1 male (sl 1.7 mm), TRPM-799.	Izumo, Shimane Prefecture (Osawa <i>et al.</i> 2016); Wakasa Bay, Kyoto Prefecture (Asakura 2006); Echizen, Fukui Prefecture (Komai 2003).
<i>Porcellanopagurus nihonkaiensis</i> Takeda, 1985	Off Tajiri (“Yamadashi”), Iwami, 15 m, 20 September 2018, 1 ovigerous female (sl 1.9 mm), TRPM-800.	Iida Bay, Ishikawa Prefecture (Takeda 1985).
Galatheidae		
<i>Galathea guttata</i> Osawa, 2004	Off Tajiri (35°59.1'N, 134°31.0'E), Iwami, 12 m, 11 October 2017, 1 male (pcl 3.1 mm), TRPM-785 (Fig. 2H).	No.
Munididae		
<i>Bathymunida brevirostris</i> (Yokoya, 1933)	Off Nagaobana, Tottori, 80 m, beam trawl, 10 September 2019, 1 female (pcl 5.4 mm), TRPM-801 (Fig. 3I).	Off Hagi, Yamaguchi Prefecture (Komai <i>et al.</i> 2002).
<i>Munida agave</i> Macpherson and Baba, 1993	Off Nagaobana, Tottori, 100 m, beam trawl, 13 July 2018, 1 ovigerous female (pcl 7.4 mm), TRPM-788 (Fig. 2I).	No.
<i>Munida pherusa</i> Macpherson and Baba, 1993	Off Nagaobana, Tottori, 100 m, beam trawl, 20 August 2018, 1 male (pcl 6.6 mm), 1 ovigerous female (pcl 7.7 mm), TRPM-802 (Fig. 2E, F).	Off Nagato and Hagi, Yamaguchi Prefecture (Komai <i>et al.</i> 2002).
<i>Paramunida tricarinata</i> (Alcock, 1894)	Off Nagaobana, Tottori, 100 m, beam trawl, 15 May 2018, 1 ovigerous female (pcl 7.9 mm), TRPM-790 (Figs 3G, 4).	No.

Table 2. Anomuran species recorded from the entire “San-in” area (cf. Motoh 2007, with deletion of wrong record of *Pagurus middendorffii* Brandt, 1851 from Kyoto Prefecture; Osawa *et al.* 2015, 2016, 2018; present study). * Occurrence records need to be verified.

Hippoidea	<i>Pagurus maculosus</i> Komai and Imafuku, 1996
Albuneidae (2 species)	<i>Pagurus minutus</i> Hess, 1865
<i>Albunea groeningi</i> Boyko, 2002	<i>Pagurus nigrivittatus</i> Komai, 2003
<i>Albunea symmysta</i> (Linnaeus, 1758)*	<i>Pagurus cf. nigrivittatus</i> Komai, 2003
Blepharipodidae (1 species)	[cf. Motoh and Toyoda 2005; Asakura 2006]
<i>Blepharipoda liberata</i> Shen, 1949	<i>Pagurus nigrofascia</i> Komai, 1996
Hippidae (1 species)	<i>Pagurus nipponensis</i> (Yokoya, 1933)
<i>Hippa truncatifrons</i> (Miers, 1878)	<i>Pagurus ochotensis</i> Brandt, 1851
Paguroidea	<i>Pagurus proximus</i> Komai, 2000
Pylochelidae (1 species)	<i>Pagurus quinquelineatus</i> Komai, 2003
<i>Pomatocheles jeffreysii</i> Miers, 1879	<i>Pagurus rathbuni</i> (Benedict, 1892)
Diogenidae (19 species)	<i>Pagurus rubrior</i> Komai, 2003
<i>Aniculus miyakei</i> Forest, 1984*	<i>Pagurus spina</i> Komai, 1994
<i>Areopaguristes japonicus</i> (Miyake, 1961)	<i>Pagurus trigonocheirus</i> (Stimpson, 1858)
<i>Clibanarius virescens</i> (Krauss, 1843)	<i>Pagurus undosus</i> (Benedict, 1892)
<i>Dardanus arrosor</i> (Herbst, 1796)	<i>Porcellanopagurus nihonkaiensis</i> Takeda, 1985
<i>Dardanus aspersus</i> (Berthold, 1845)	<i>Spiropagurus spiriger</i> (De Haan, 1849)
<i>Dardanus crassimanus</i> (H. Milne Edwards, 1836)	<i>Turleania senticosa</i> (McLaughlin and Haig, 1996)
<i>Dardanus impressus</i> (De Haan, 1849)	
<i>Dardanus pedunculatus</i> (Herbst, 1804)*	Lithodoidea
<i>Dardanus lagopodes</i> (Forskål, 1775)	Hapalogastriidae (2 species)
<i>Dionege edwardsii</i> (De Haan, 1849)	<i>Hapalogaster dentata</i> (De Haan, 1849)
<i>Dionege izanamiiae</i> Asakura, 2006	<i>Oedignathus inermis</i> (Stimpson, 1860)
<i>Diogenes nitidimanus</i> Terao, 1913	Lithodidae (1 species)
<i>Dionege penicillatus</i> Stimpson, 1858	<i>Paralithodes camtschaticus</i> (Tilesius, 1815)
<i>Diogenes pallescens</i> Whitelegge, 1897	Galatheoidea
<i>Diogenes spinifrons</i> (De Haan, 1849)	Galatheididae (5 species)
<i>Paguristes digitalis</i> Stimpson, 1858	<i>Galathea guttata</i> Osawa, 2004
<i>Paguristes gonagrus</i> (H. Milne Edwards, 1836)	<i>Galathea cf. ohshimai</i> Miyake and Baba, 1967
<i>Paguristes ortmanni</i> Miyake, 1978	[cf. Motoh and Toyoda 2005]
<i>Paguristes versus</i> Komai, 2001	<i>Galathea orientalis</i> Stimpson, 1858
Paguridae (33 species)	<i>Galathea peitho</i> Macpherson and Robainas-Barcia, 2015
<i>Anapagurus japonicus</i> Ortmann, 1892	<i>Lauriea simulata</i> Macpherson and Robainas-Barcia, 2013
<i>Catapaguroides fragilis</i> (Melin, 1939)	Munididae (6 species)
<i>Catapaguroides japonicus</i> de Saint Laurent, 1968	<i>Bathymunida brevirostris</i> (Yokoya, 1933)
<i>Diacanthurus ophthalmicus</i> (Ortmann, 1892)*	<i>Cervimunida princeps</i> Benedict, 1902
<i>Elassochirus cavimanus</i> (Miers, 1879)	<i>Munida agave</i> Macpherson and Baba, 1993
<i>Labidochirus anomalus</i> (Balss, 1913)	<i>Munida japonica</i> Stimpson, 1858
<i>Lophopagurus triserratus</i> (Ortmann, 1892)	<i>Munida pherusa</i> Macpherson and Baba, 1993
<i>Nematopagurus australis</i> (Henderson, 1888)	<i>Paramunida tricarinata</i> (Alcock, 1894)
<i>Nematopagurus tricarinatus</i> (Stimpson, 1858)	Porcellanidae (8 species)
<i>Pagurus decimbranchiae</i> Komai and Osawa, 2001	<i>Enosteoides ornatus</i> (Stimpson, 1858)
<i>Pagurus conformis</i> De Haan, 1849	<i>Pachycheles hertwigi</i> Balss, 1913
<i>Pagurus constans</i> (Stimpson, 1858)	<i>Pachycheles stevensii</i> Stimpson, 1858
<i>Pagurus erythrogrammus</i> Komai, 2003	<i>Petrolisthes coccineus</i> (Owen, 1839)
<i>Pagurus filholi</i> (De Man, 1887)	<i>Petrolisthes japonicus</i> (De Haan, 1849)
<i>Pagurus japonicus</i> (Stimpson, 1858)	<i>Pisidia serratifrons</i> (Stimpson, 1858)
<i>Pagurus lanuginosus</i> De Haan, 1849	<i>Porcellana pulchra</i> Stimpson, 1858
	<i>Porcellanella triloba</i> White, 1852

nese coast of the Sea of Japan: *Naushonia japonica* Komai, 2004; *Upogebia issaeffi*; *U. major*; and *U. yokoyai* Makarov, 1938 (e.g., Miyake *et al.* 1962; Sakai 1982; Komai 2004; Osawa *et al.* 2014a). *Austinoergia narutensis* is the fifth gebiidean species in this region. The distribution of the three *Upogebia* species extends north to the Russian coast (Peter the Great Bay; Marin *et al.* 2013), and the records of the three species from “San’in” area (Yamaguchi, Shimane, Tottori, Hyogo, and Kyoto Prefectures; Fig. 1B), the western

Japanese coast of the Sea of Japan, are respective shown as follows: Hyogo for *U. issaeffi*, Tottori for *U. major*, and Shimane for *U. yokoyai* (Miyake *et al.* 1962; Sakai 1982; Osawa *et al.* 2014a). With regard to *Austinoergia*, *A. monospina* Liu and Liu, 2012 and *A. wuhsienweni* are recorded from the southwestern coast of Korea (Jeollanam-do), north of Tsushima Strait (Kim and Kim 2017), but *A. narutensis* has not been recorded from the continental coast of the Sea of Japan. In Japan, *A. wuhsienweni* is recorded only from Na-

gasaki Prefecture (Sakai 2006). *Naushonia japonica*, the remaining gebiidean species hitherto recorded from the Sea of Japan, has been known only from Shimonoseki, Yamaguchi Prefecture (type locality; Komai 2004), and Katsuura, Chiba Prefecture on the Pacific coast of Honshu mainland, central Japan (Komai and Anker 2015).

With regard to Anomura, a series of recent studies has revealed that 54 species (26 genera in nine families) occur in Shimane Prefecture including the Oki Islands off the “San’in” coast (cf. Osawa *et al.* 2014b, 2015, 2016, 2018). Prior to Osawa *et al.* (2014b), the knowledge on the faunal composition of the area was very poor because only 21 species were known from there. As shown in Introduction, Nishimura (1992) discussed on seven zoogeographical (zooclimatic) zones categorized in Japanese waters (tropical, subtropical, warm temperate, moderate temperate, cool temperate, subboreal, and boreal zones). Species primary found in the three temperate zones consist of East Asian endemic elements, whereas those showing tropical or subtropical distribution correspond to Indo-West Pacific elements. Osawa *et al.* (2014b) preliminarily interpreted that the anomuran fauna of the coast of Shimane Prefecture is composed primarily of the East Asian endemic elements (59%; 32 species of the total species number, 54) and the Indo-West Pacific elements [31%; 17 species of the total species number; all the species numbers are supplemented by Osawa *et al.* (2015, 2016, 2018)]. This is not contradicted by the fact that the area around Shimane Prefecture is located at temperate zone of East Asia and is likely a boundary between the warm temperate and moderate temperate zones in the coast of the Sea of Japan suggested by Nishimura (1992).

Meanwhile, 31 anomuran species are hitherto recorded from Tottori Prefecture which is presently studied area and situated east to Shimane Prefecture [cf. Motoh 2007: table 2; Osawa *et al.* 2015: table 1; with their inadvertently omitted record of *Lophopagurus triserratus* (Ortmann, 1892) from off the prefecture by Yokoya 1933, as *Eupagurus* Brandt, 1851]. In addition to these species, examination of specimens recently collected from Tottori Prefecture by the second author has shown that 16 species, including five species new to the Sea of Japan reported above, are new records from the area (Table 1; 47 species in total). The increase of the recorded species is due to the sampling effort in the sublittoral zone using scuba and trawls.

The inventory of anomuran fauna in the areas of Shimane and Tottori Prefectures is still incomplete, and knowledge on the faunal composition is still limited. There is little doubt that future study will reveals the presence of more species in the areas, particularly from the sublittoral zone between 10 and 200 m where only a few reports on anomurans are present (cf. Osawa *et al.* 2014b, 2015). Including published records from the other three prefectures (Yamaguchi, Hyogo, and Kyoto), 79 anomuran species are known from the coasts and off-shores of entire “San’in” area, but the records of some species need to be verified because no positive information on the species identification were given for the reported material (Table 2). For example, “Menaga-hon-

yadokari”, Japanese name for *Diacanthurus ophthalmicus* (Ortmann, 1892), was recorded from the eastern coast of the estuarine lake Nakaumi (Tottori Prefecture) by Yonago City (1997: table 2–5, written by Japanese and the sole record of the species from “San’in” area), but the pagurid species is unexceptionally known from the off-shore at depths greater than 65 m (cf. McLaughlin *et al.* 2007). The material reported by Yonago City (1997) high probably belongs to *Pagurus filholi* (De Man, 1887) or *P. minutus* Hess, 1865, because these are only hermit crab species found in the intertidal or shallow subtidal zone of Nakaumi and its adjacent area (Osawa *et al.* 2014b). These show that it is premature at present to reasonably discuss on the faunal and biogeographical characters of the “San’in” area. Reliable information on species based on the specimens collected and allowed re-verification is needed to know precise faunal composition of the local area.

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