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Two galatheid associates of crinoids from the Ryukyu Islands (Decapoda: Anomura: Galatheidae), with their ecological notes

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***Abstract.*—*Galathea amboinensis* De Man, 1888 and *G. inflata* Potts, 1915, both known as associates of shallow water comatulid crinoids, are reported for the first time from Japan. In the Ryukyu Islands, *Galathea inflata* was found on 13 species of crinoids but most commonly on *Comanthus parvicirrus* (Müller) and *Comaster schlegelii* (Carpenter). *Galathea amboinensis* was recorded from 10 crinoid species but more often on *Capillaster multiradiatus* (Linnaeus) than on other crinoids. Heterosexual pairs of *G. inflata* were found on 26.3 % of host crinoids (n=57), and all females were ovigerous. Megalopae of both galatheids were found on hosts, indicating that the larvae settled on crinoids at the megalopa stage.**

Introduction

In 1995, one of us (YF) collected some unusual galatheids on crinoids during studies of the crinoid fauna of the Ryukyu Islands. These galatheids were then identified by KB as *Galathea amboinensis* de Man, 1888 and *G. inflata* Potts, 1915. *Galathea amboinensis* had been recorded from Ambon, Torres Strait, Moluccas and Sulu Archipelago and *G. inflata* from Torres Strait and the Molucca Islands, both as associates of comatulid crinoids (see Baba, 1979, 1988). Since then special attention has been paid to host specificity of these two galatheids, by collecting as many crinoids as possible. A total of 543 crinoids distributed among 36 species have been collected, and 108 specimens of the two galatheids have been obtained from 80 of the crinoids collected. The material at hand now provides new information on color in life, host preference, stage of settlement on hosts, and size in relation to sex determination of the galatheids.

The collections and observations were conducted by YF in coastal waters of Okinawa Island (five locations on the west coast: Sesoko, Motobu-cho; Cape Maeda, Onna-son; Udui, Onna-son; Mizugama, Kadena-cho; and Sunabe, Chiatan-cho) by SCUBA diving during the day and night. Each crinoid was collected by enclosing it in a plastic bag that prevented the escape of any crustacean associates. The crinoids were identified with the help of Dr. Ichizo Kogo, a specialist of crinoid taxonomy, and by consultation with the following papers: Clark (1931, 1941, 1947), Clark & Rowe (1971), Hoggett & Rowe (1986), Kogo (1998), Messing (1998), Rowe *et al.* (1986), and Utinomi & Kogo (1965, 1968). The postorbital carapace length (CL) indicates size of the galatheids.

Galathea amboinensis De Man, 1888
Fig. 1

Material examined.—See Table 1.

Recognition characters.—Carapace with lateral margins strongly convex, bearing 5 spines behind anterior cervical groove, gastric region without spines, anterior branchial region with continuous ridges. Epipods present on chelipeds and first two walking legs. Third maxilliped

Table 1. The material examined of Galathea amboinensis. Indet. = indeterminate; FG = female gonopores present; SP = short pleopods.

Date	locality	Depth (m)	Host	Sex	Size
26.04.1996	Cape Maeda	7.3	*Capillaster multiradiatus*	Indet. (FG, SP)	2.70
26.04.1996	Cape Maeda	7.2	*Capillaster multiradiatus*	Indet. (FG, SP)	2.25
12.03.1997	Cape Maeda	6.3	*Capillaster multiradiatus*	Megalopa	0.99
				Indet. (SP)[1)]	1.39
				Indet. (FG, SP)	3.80
12.03.1997	Cape Maeda	5.5	*Capillaster multiradiatus*	Megalopa	0.99
				Megalopa	0.92
				Megalopa	0.99
28.03.1997	Cape Maeda	8.7	*Capillaster multiradiatus*	Megalopa	0.86
				Megalopa	1.12
28.03.1997	Cape Maeda	6.8	*Capillaster multiradiatus*	Indet. (FG, SP)	5.60
				Indet. (FG, SP)	4.50
28.03.1997	Cape Maeda	7.1	*Capillaster multiradiatus*	Megalopa	1.06
28.03.1997	Cape Maeda	5.9	*Capillaster multiradiatus*	Indet. (FG, SP)	1.80
28.03.1997	Cape Maeda	7.1	*Capillaster multiradiatus*	Megalopa	1.06
03.04.1997	Cape Maeda	8.1	*Capillaster multiradiatus*	Indet. (SP)[1)]	1.30
01.12.1997	Mizugama	7.1	*Comanthus gisleni*	Indet. (FG, SP)	4.60
09.07.1997	Cape Maeda	5.9	*Comanthus parvicirrus*	Indet. (FG, SP)	1.85
				Indet. (FG, SP)	1.25
11.09.1997	Cape Maeda	22.5	*Comanthus* sp.	Indet. (FG, SP)	1.80
21.07.1996	Mizugama	6.8	*Comaster nobilis*	Indet. (FG, SP)	3.50
21.07.1996	Mizugama	6.8	*Comaster nobilis*	ov. ♀	5.50
12.05.1995	Mizugama	9.0	*Comaster nobilis*	Indet. (FG, SP)	2.18
16.08.1995	Cape Maeda	12.5	*Comaster nobilis*	Megalopa	1.03
03.06.1999	Udui	29.8	*Comatella nigra*	Indet. (FG, SP)	3.20
29.04.1997	Cape Maeda	7.1	*Dichrometra* sp.	Megalopa	1.05
				Indet. (FG, SP)	1.55
03.08.1996	Mizugama	7.8	*Phanogenia gracilis*	Indet. (FG, SP)	2.90
14.10.1996	Mizugama	9.7	*Phanogenia gracilis*	ov. ♀	7.28
29.04.1997	Cape Maeda	8.2	*Stephanometra spicata*	Indet. (FG, SP)	2.80
				Megalopa	0.99
12.05.1995	Mizugama	7.3	*Tropiometra afra macrodiscus*	Indet. (FG, SP)	2.30

1) Presence or absence of female gonopres was not determined because of poor conditions of the specimen.

ischia with 15–17 denticles on mesial ridge, merus with two strong spines on flexor margin and 1 distal spine on extensor margin. Chelipeds spinose and short relative to their width, carpus at most twice as long as broad.

Coloration.—Dark brown and gray-white stripes on carapace and abdomen;

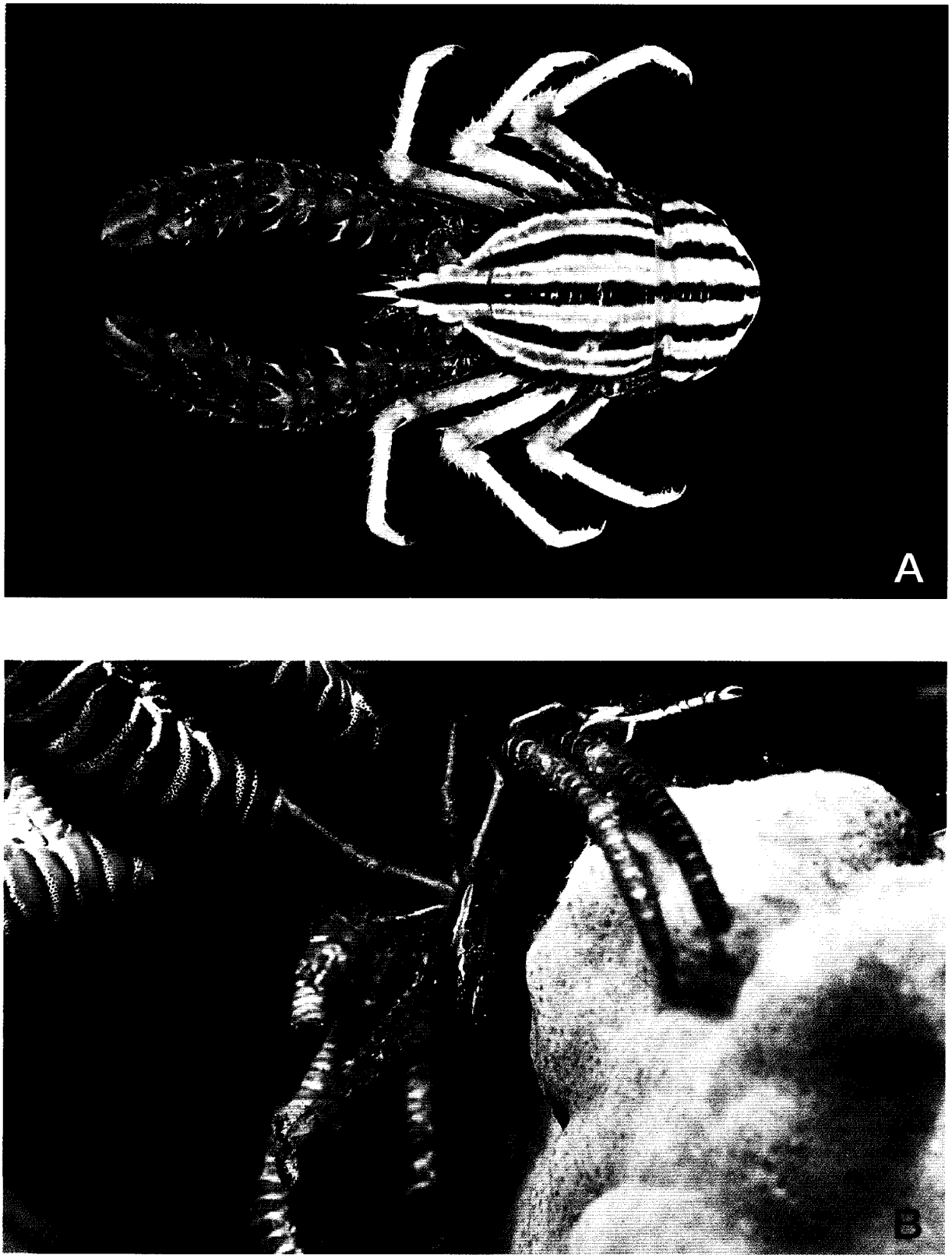

Fig. 1. *Galathea amboinensis* De Man: A, ovigerous female (CL= 7.28 mm), collected from *Phanogenia gracilis* (Hartlaub); B, living posture at night, associated with *Capillaster multiradiatus* (Linnaeus). Photos taken by Y. Fujita.

chelipeds gray-white, with dark brown bands; walking legs whitish (Fig. 1A).

Hosts.—The present material was associated with 10 species of crinoids (Tables 1, 3): *Capillaster multiradiatus* (Linnaeus), *Phanogenia gracilis* (Hartlaub), *Comatella nigra* (Carpenter), *Comaster nobilis* (Carpenter), *Comanthus parvicirrus* (Müller), *C. gisleni* Rowe *et al.*, *Comanthus* sp. 1, *Dichrometra* sp., *Stephanometra spicata* (Carpenter), and *Tropiometra afra macrodiscus* (Hara).

Potts (1915) recorded *Comanthus annulatum* as a host of *G. amboinensis*. By consultation with Clark (1915, 1931) and Rowe *et al.* (1986), this comatulid may now be referable to *C. parvicirrus,* but its systematic status is still unclear. Also, "*Comanthina schlegeli,*" another host reported by Baba (1979), has recently been divided into two species, *Comaster schlegelii* (Carpenter) and *Comaster nobilis* (Carpenter) (see Rowe *et al.*, 1986; Messing, 1998). Thus, at least seven (excluding *C. nobilis, C. parvicirrus,* and *Comanthus* sp. 1) of the host crinoids listed above can be recorded here as new hosts.

Range.—Previously recorded from Ambon (type locality), Torres Strait, Moluccas and Sulu Archipelago (de Man, 1888; Potts, 1915; Baba, 1979, 1988). The present material constitutes the first record of *G. amboinensis* from Japan.

Ecological notes.—*Galathea amboinensis* is found between the cirri and basal parts of the arms of crinoids such as *Capillaster multiradiatus, Comatella nigra, Dichrometra* sp., *Stephanometra spicata* and *Tropiometra afra macrodiscus*, which bear well developed cirri (Fig. 1B). When host crinoids have cirri reduced or absent (*Phanogenia gracilis, Comanthus gisleni, C. parvicirrus, C.* sp. 1, and *Comaster nobilis*), the galatheids are found on substrate under the host. Night observations revealed that *G. amboinensis* often ventured slightly away from the host.

The galatheids found on 16 of 23 host crinoids were solitary, and two or three individuals (mostly megalopae and juveniles of undetermined sex) were found on each of the remaining 7 hosts. No heterosexual pairs were found. No males were collected and all females were ovigerous.

Frequency of occurrence of the galatheids on each host species is shown in Table 3. Capillaster multiradiatus housed more than half the total number of the galatheids collected.

Co-inhabitants on the crinoids include: *Palaemonella pottsi* (Borradaile), *Parapontonia nudirostris* Bruce, *Periclimenes affinis* (Zehantner), *P. amboinensis* (De Man), *P. ceratophthalmus* Borradaile, *P. commensalis* Borradaile, *P. pilipes* Bruce & Zmarzly, *Pontoniopsis comanthi* Borradaile, *Synalpheus demani* Borradaile, *Synalpheus stimpsoni* (De Man), *Synalpheus* sp., *Galathea inflata, Harrovia longipes* Lanchester, and *Permanotus purpureus* (Gordon). Further details will be reported elsewhere (Fujita, unpublished).

Measurements.—Megalopae, CL = 0.86–1.12 mm; sex indeterminate (female gonopores present, pleopods short), CL=1.30–5.60 mm; ovigerous females, CL=5.5, 7.28 mm.

Galathea inflata Potts, 1915

Fig. 2

Material examined.—See Table 2.

Recognition characters.— Carapace lateral margins convex, bearing 6 spines behind anterior cervical groove; no gastric spines; anterior branchial region with scale-like ridges. Epipods present on chelipeds and first and second walking legs. Ischium of third maxilliped with more than 23 denticles on mesial ridge; merus with 3 spines on flexor margin, 2 spines on extensor margin. Chelipeds long relative to their width, carpus more than twice as long as broad.

Table 2. The material examined of *Galathea inflata*. Indet. = sex indeterminate; FG = female gonopores present; No FG = Female gonopores absent; SP = short pleopods.

Date	locality	Depth (m)	Host	Sex	Size
12.03.1997	Cape Maeda	6.7	*Capillaster multiradiatus*	Megalopa	1.15
12.03.1997	Cape Maeda	5.1	*Capillaster multiradiatus*	Indet. (No FG, SP)	1.40
28.03.1997	Cape Maeda	6.2	*Capillaster multiradiatus*	Megalopa	1.16
28.03.1997	Cape Maeda	6.7	*Capillaster multiradiatus*	Megalopa	1.20
				Indet. (FG, SP)	1.85
02.04.1997	Cape Maeda	6.2	*Capillaster multiradiatus*	Indet. (FG, SP)	2.30
02.04.1997	Cape Maeda	6.3	*Capillaster multiradiatus*	Indet. (No FG, SP)	1.40
02.04.1997	Cape Maeda	5.5	*Capillaster multiradiatus*	Indet. (No FG, SP)	1.50
03.04.1997	Cape Maeda	6.9	*Capillaster multiradiatus*	Indet. (No FG, SP)	2.00
				ov. ♀	3.50
03.04.1997	Cape Maeda	7.9	*Capillaster multiradiatus*	♀	4.62
10.01.1997	Mizugama	6.2	*Clarkcomanthus littoralis*	♀	3.80
12.05.1997	Cape Maeda	28.0	*Comanthus alternans*	Indet. (No FG, SP)	1.85
03.08.1996	Mizugama	9.7	*Comanthus parvicirrus*	ov. ♀	5.90
				♂	3.30
15.11.1996	Mizugama	8.0	*Comanthus parvicirrus*	♂	3.10
				ov. ♀	5.80
21.11.1996	Mizugama	8.4	*Comanthus parvicirrus*	♀	6.00
10.01.1997	Mizugama	7.4	*Comanthus parvicirrus*	ov. ♀	5.40
30.01.1997	Mizugama	6.8	*Comanthus parvicirrus*	♂	5.20
20.03.1997	Mizugama	7.6	*Comanthus parvicirrus*	♂	4.20
				ov. ♀	3.80
20.03.1997	Mizugama	6.1	*Comanthus parvicirrus*	♂	4.20
25.03.1997	Mizugama	6.2	*Comanthus parvicirrus*	♂	3.36
03.04.1997	Cape Maeda	7.6	*Comanthus parvicirrus*	♀	5.32
24.06.1999	Cape Maeda	6.8	*Comanthus parvicirrus*	ov. ♀	3.70
				♂	5.10
12.06.1999	Cape Maeda	5.2	*Comanthus parvicirrus*	Indet. (FG, SP)	1.85
13.04.1997	Mizugama	5.5	*Comanthus parvicirrus*	♂	4.62
				ov. ♀	5.32
21.04.1997	Mizugama	7.6	*Comanthus parvicirrus*	♂	3.78
				ov. ♀	5.18
21.04.1997	Mizugama	4.9	*Comanthus parvicirrus*	Indet. (No FG, SP)	1.10
14.05.1997	Mizugama	8.0	*Comanthus parvicirrus*	Indet. (FG, SP)	1.60
27.08.1997	Sesoko	3.2	*Comanthus parvicirrus*	ov. ♀	5.60
				♂	3.30
31.08.1997	Sesoko	5.7	*Comanthus parvicirrus*	Megalopa	0.96
				♂	5.60
31.08.1997	Sesoko	6.1	*Comanthus parvicirrus*	Indet. (No FG, SP)	1.75
				♂	3.30
				ov. ♀	4.40
31.08.1997	Sesoko	6.1	*Comanthus parvicirrus*	♂	5.18
				ov. ♀	5.60
31.08.1997	Sesoko	6.3	*Comanthus parvicirrus*	♂	4.48
				ov. ♀	5.74
12.10.1997	Mizugama	7.4	*Comanthus* sp	♀	3.30
26.08.1997	Sesoko	9.8	*Comaster nobilis*	♂	2.40
27.04.1996	Mizugama	2.0	*Comaster schlegelii*	♂	4.40

Table 2. Continued.

Date	locality	Depth (m)	Host	Sex	Size
27.12.1996	Mizugama	6.7	*Comaster schlegelii*	ov. ♀	5.70
				♂	4.40
07.01.1997	Mizugama	8.1	*Comaster schlegelii*	♂	5.90
30.01.1997	Mizugama	4.8	*Comaster schlegelii*	♂	4.00
				ov. ♀	4.70
30.01.1997	Mizugama	5.1	*Comaster schlegelii*	♂	3.50
13.04.1997	Mizugama	5.6	*Comaster schlegelii*	♂	5.40
21.04.1997	Mizugama	4.7	*Comaster schlegelii*	ov. ♀	5.04
21.04.1997	Mizugama	6.2	*Comaster schlegelii*	Indet. (No FG, SP)	1.75
21.04.1997	Mizugama	4.7	*Comaster schlegelii*	Indet. (FG, SP)	1.50
22.04.1997	Mizugama	5.2	*Comaster schlegelii*	♂	5.32
				ov. ♀	5.60
22.04.1997	Mizugama	6.0	*Comaster schlegelii*	♂	5.60
22.04.1997	Mizugama	5.5	*Comaster schlegelii*	♂	5.60
				ov. ♀	6.30
13.10.1997	Mizugama	6.9	*Comatella maculata*	ov. ♀	4.30
12.10.1997	Mizugama	8.3	*Comatella nigra*	♀	3.70
15.11.1996	Mizugama	7.8	*Comatella stelligera*	♂	3.90
29.08.1996	Mizugama	5.5	*Phanogenia gracilis*	Indet. (No FG, SP)	2.30
14.11.1997	Mizugama	6.6	*Phanogenia gracilis*	ov. ♀	5.30
				♂	4.20
02.04.1997	Cape Maeda	4.4	*Stephanometra spicata*	Indet. (No FG, SP)	1.40
09.09.1997	Cape Maeda	6.1	*Stephanometra spicata*	Megalopa	1.05
07.01.1997	Mizugama	9.0	*Tropiometra afra macrodiscus*	Indet. (No FG, SP)	1.10
30.04.1995	Mizugama	6.6	*Tropiometra afra macrodiscus*	Indet. (No FG, SP)	1.45
12.05.1995	Mizugama	8.1	*Tropiometra afra macrodiscus*	Indet. (No FG, SP)	1.58
12.05.1995	Mizugama	7.3	*Tropiometra afra macrodiscus*	Indet. (No FG, SP)	1.65
25.07.1995	Sunabe	7.6	*Tropiometra afra macrodiscus*	ov. ♀	3.40

Coloration.—Two color patterns were recognized in the material examined:

Color pattern 1 (Fig. 2A): Body dark brown ground color, with 2 yellow- white stripes on carapace extending backward to join each other on abdomen; chelipeds dark brown, bearing white spot on tip of each finger; walking legs also dark brown, with yellow-white band on distal portion of propodus, dactyls distally whitish.

Color pattern 2 (Fig. 2B): Very similar to pattern 1 but ground color dark green. This coloration was seen only on specimens from *Comaster schlegelii*, the ventral side of which is green.

Hosts.—The present material was found in association with the following 13 species of crinoids: *Capillaster multiradiatus* (Linnaeus), *Phanogenia gracilis* (Hartlaub), *Comatella maculata* (Carpenter), *Comatella nigra* (Carpenter), *Comatella stelligera* (Carpenter), *Comanthus alternans* (Carpenter), *Comanthus parvicirrus* (Müller), *Comanthus* sp. 1, *Comaster nobilis* (Carpenter), *Comaster schlegelii* (Carpenter), *Clarkcomanthus littoralis* (Carpenter), *Stephanometra spicata* (Carpenter) and *Tropiometra afra macrodiscus* (Hara) (see Table 3).

The type material was known from "*Comanthus annulatum*" (see Potts, 1915; see above under *G. amboinensis* for systematic status of this host). Baba (1979) reported that the Moluccan material was

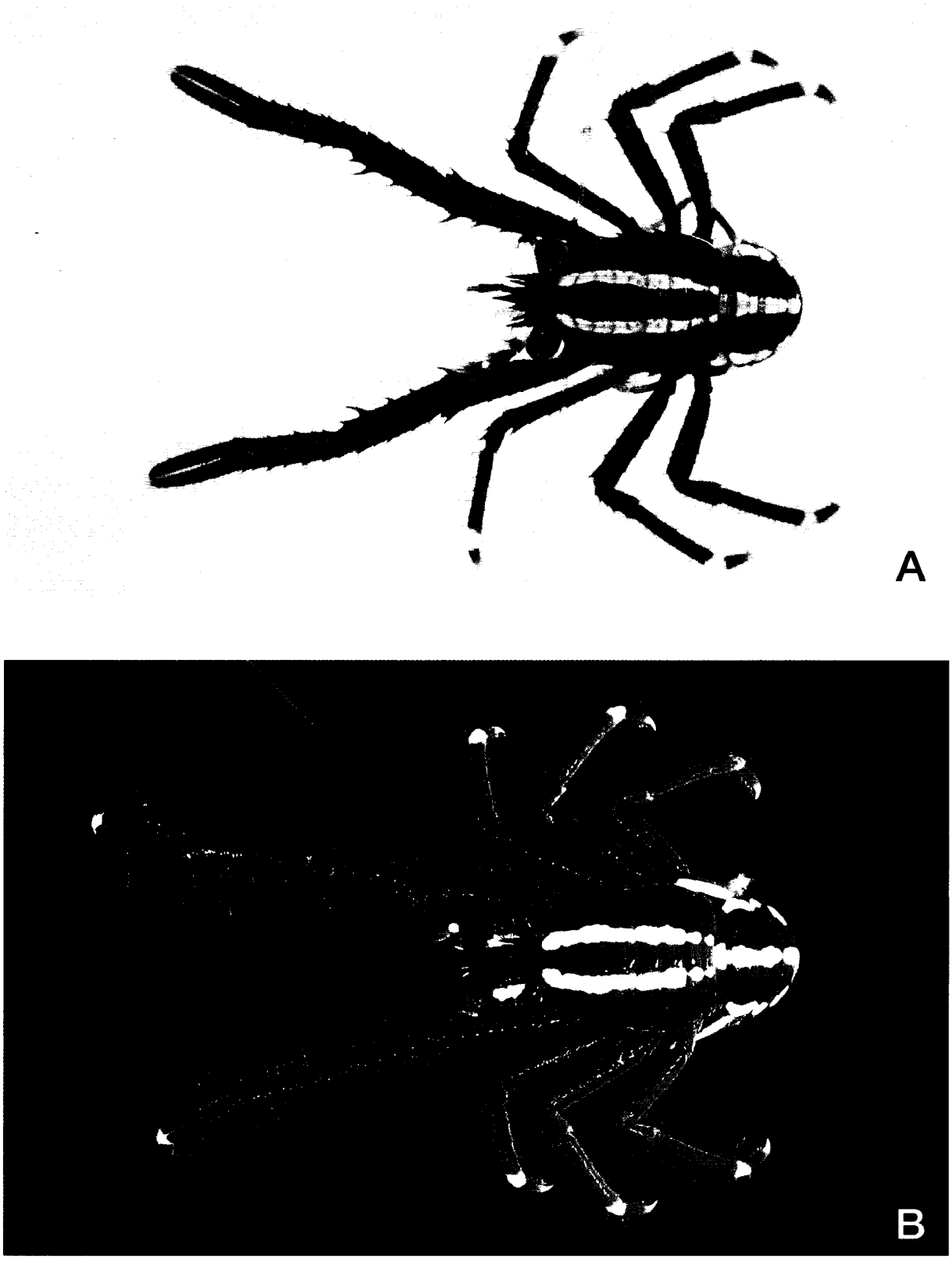

Fig. 2. *Galathea inflata* Potts: A, ovigerous female (CL= 3.80 mm), collected from *Comanthus parvicirrus* (Müller); B. male (CL= 5.90 mm), collected from *Comaster schlegelii* (Carpenter). Photos taken by Y. Fujita.

found on *Comanthus bennetti* (now called *Oxycomanthus bennetti*), *Comanthus parvicirrus* and *Comanthina schlegeli* (= *Comaster schlegelii* or *C. nobilis*; see above). At least eight species of the crinoids (excluding *C. parvicirrus, Comanthus* sp. 1, *C. nobilis, C. schlegelii, C. littoralis*) listed above apparently represent new hosts.

Range.—Previously known from Torres Strait (type locality; Potts, 1915) and the Molucca Islands (Baba, 1979). *Galathea inflata* is recorded from Japanese waters for the first time.

Ecological notes.—Like *G. amboinensis, G. inflata* was found on crinoids irrespective of the character of the cirri of the host—well developed or reduced. When associated with C. *parvicirrus* and *C. schlegelii* that usually live in crevices on coral reefs, the galatheids were often found on the substrate.

Galathea inflata was most commonly found on *C. parvicirrus* (the galatheids were found on 20 of 31 = 64.5% of crinoids collected) and taken on 12 of 34 = 35.3% of *C. schlegelii* collected (Table 3).

Heterosexual pairs were found on 15 of 57 host crinoids: on 10 of 20 *C. parvicirrus,* 4 of 12 *C. schlegelii*, and 1 of 2 *Phanogenia gracilis*. The females of all heterosexual pairs were ovigerous and mostly larger than their accompanying males. The remaining hosts were mostly occupied by single galatheids including males, ovigerous females, non-ovigerous females, juveniles (sex indeterminate) and megalopae. Two other pairs were found: an ovigerous female and juvenile (sex indet., bearing no female gonopores); one megalopa and juvenile (sex indet., bearing female gonopores).

Co-inhabitants found on the crinoids were: *Palaemonella pottsi, Parapontonia nudirostris, Periclimenes affinis, P. amboinensis, P. ceratophthalmus, P. commensalis, Pontoniopsis comanthi, Synalpheus demani, Synalpheus stimpsoni, Synalpheus* sp., *Galathea amboinensis* and *Permanotus purpureus*. More detail will be reported later elsewhere (Fujita, unpublished).

Measurements.—Megalopae, CL=0.96–1.20 mm; incomplete males (no genital pores on second walking legs, no gonopods), CL=1.10–2.30 mm; incomplete females (gonopores on second walking legs, no female pleopods), CL=1.50–2.30 mm; males, CL=2.40–5.90 mm; females, CL=3.30–6.30 mm (ovigerous females from CL=3.40 mm).

Discussion

Using the numerous records of crinoid symbionts in the literature, Potts (1915) was the first to focus upon crustacean-crinoid associations, in which the present two species of galatheids were included. These associations have also been discussed by Fishelson (1974), Zmarzly (1984), and Fabricius & Dale (1993), based upon material from shallow waters in the Red Sea, Great Barrier Reef, and Eniwetok Atoll. So far as the shallow water galatheid symbionts are concerned, four species are known: *Allogalathea elegans* (Adams & White, 1848) (see Potts, 1915; Barnard, 1950; Holthuis, 1953; Lewinsohn, 1969; Baba, 1979), *Galathea amboinensis* (see Potts, 1915, under *G. minuta* Potts; Baba, 1979), *Galathea genkai* Miyake & Baba, 1966 (see Lewinsohn, 1969; Fishelson, 1974), and *Galathea inflata* (see Potts, 1915; Baba, 1979). Miyake (1938) noted that *Galathea acanthomera* Stimpson, 1858 (=now *G. orientalis* Stimpson, 1858) was taken from a crinoid. Utinomi & Kogo (1965) reported *G. orientalis* and *G.* sp. as associates of crinoids. However, *G. orientalis* is usually found to be free living in Japanese coastal waters. Fabricius & Dale (1993) listed three unidentified species of *Galathea* that they found on crinoids from the Great Barrier Reef. Eeckhaut *et al.* (1998) reported two spe-

cies of galatheids (without giving scientific names) on crinoids from Papua-New Guinea.

Host specificity

Our study shows that *Galathea amboinensis* is associated with 10 species and *G. inflata* with 13 species of crinoids. Compared with the pontoniine *Periclimenes novaecaledoniae* and the alpheid *Synalpheus demani,* both known from single crinoids (Bruce, 1982), host specificity of these galatheids is rather low. This is also true for *Allogalathea elegans*, which has been recorded from nine species of crinoids (Baba, 1979). However, other galatheids are more specialized: *Galathea genkai* is known from three crinoid hosts (see above for references), and a deep-sea species of the galatheid genus *Munidopsis* is known from two crinoids (Rice & Miller, 1992).

Although 15 host crinoid species are known in the Ryukyu Islands, colonization rate (indicated by percent occurrence, i.e. the number of hosts found by the galatheids) of *Galathea inflata* is relatively high for *Comanthus parvicirrus* (64.5%, n=31) and *Comaster schlegelii* (35.3%, n=34), while that of *G. amboinensis* is highest for *Capillater multiradiatus* (21.7%, n=46). Zmarzly (1984) noted that 54 % (n=13) of *Comanthina schlegelii* (= now *Comaster schlegelii*) housed *Allogalathea elegans*, as also did 23 % (n=73) of *Comanthus bennetti* (= now *Oxycomanthus bennetti*). Fabricius & Dale (1993) reported that the species of *Galathea* and *Allogalathea* they observed were not found on those crinoids that lack cirri. This does not seem to be always true, because both the species we report here have been taken from hosts having reduced cirri. In addition, at least one of the previously reported host crinoids for *A. elegans* (*C. parvicirrus*) has reduced cirri.

Potts (1915) reported that galatheids leave their host when disturbed but when they have been detached they swim back immediately to the host.

Sex determination in relation to size

Our study is the first to report that galatheid larvae settle on crinoids at the megalopa stage (Tables 1, 2).

From the megalopa *Galathea inflata* grows into one of two sexually indeterminate forms (juveniles): one having the second walking legs with gonopores but with short pleopods (CL=1.50–2.30 mm), and the other lacking both female gonopores and male gonopods (CL= 1.10–2.30 mm). Subsequently they attain sizes that allow discrimination of their sex at CL=2.40 mm for males and 3.30 mm for females. The male is determined by the presence of a pair of gonopods on each of the first and second abdominal segments, and the female by the presence of gonopores on the coxae of the second walking legs and elongate, biramous pleopods. Dr. Yasushi Fukuda, Kyushu Luther College, Kumamoto reared larvae of *Galathea orientalis* Stimpson, 1858, up to the fourth crab stage under laboratory conditions. He found that it was at the second stage that female gonopores became discernible but the pleopods were not typical of the sexes through the fourth crab stage (Fukuda, unpublished). The size distribution displayed by *G. inflata* suggests that sex differentiation begins at the very early crab stage, morphologically represented by the presence of male or female gonopores (although the male gonopores are hardly visible under microscope) and then they develop either male or female pleopods.

On the other hand, *G. amboinensis* has no such size/sex distribution. Males have not been collected and all the material examined (except megalopae and ovigerous females) bear distinct female gonopores but no typical female pleopods, even in larger specimens up to CL=5.6 mm. The absence of males in our collection may be the result of sampling bias. No externae or scars of rhizocephalan parasites were

Table 3. Occurrence of two galatheid symbionts on crinoids found in Okinawa Island. N = number of crinoids collected; TG = total number of galatheids found; C = number of host crinoids; G = number of galatheids on a single host; percent occurrence = number of host crinoids/number of crinoids collected.

Crinoids	N	*G. amboinensis* (n=32) TG/C (G)	Percent occurrence	*G. inflata* (n=76) TG/C (G)	Percent occurrence
Family Comasteridae					
Capillaster multiradiatus (Linnaeus)	46	16/10 (1–3)	21.7	11/9 (1–2)	19.6
Capillaster sentosus (Carpenter)	2				
Comatella maculata (Carpenter)	14			1/1 (1)	7.1
Comatella nigra (Carpenter)	8	1/1(1)	12.5	1/1 (1)	12.5
Comatella stelligera (Carpenter)	12			1/1 (1)	8.3
Comatella sp.	10				
Comissia magnifica Gislén	19				
Comanthus alternans (Carpenter)	34			1/1 (1)	2.9
Comanthus gisleni Rowe *et al.*	13	1/1 (1)	7.7		
Comanthus parvicirrus (Müller)	31	2/1 (2)	3.2	32/20 (1–3)	64.5
Comanthus sp. 1	13	1/1 (1)	7.3	1/1 (1)	7.7
Comanthus sp. 2	2				
Comanthus sp. 3	1				
Comaster schlegelii (Carpenter)	34			16/12 (1–2)	35.3
Comaster nobilis (Carpenter)	47	4/4 (1)	8.5	1/1 (1)	2.1
Clarkcomanthus littoralis (Carpenter)	37			1/1 (1)	2.7
Oxycomanthus bennetti (Müller)	32				
Oxycomanthus solaster (A. H. Clark)	3				
?*Oxycomanthus comanthipinna* (Gislén)	1				
Phanogenia gracilis (Hartlaub)	44	2/2 (1)	4.5	3/2 (1–2)	4.5
Phanogenia multibrachiata (Carpenter)	1				
Phanogenia typica Lovén	1				
Family Himerometridae					
Himerometra bartschi A. H. Clark	2				
Himerometra robustipinna (Carpenter)	7				
Family Mariametridae					
Lamprometra palmata (Müller)	15				
Stephanometra echinus (A. H. Clark)	3				
Stephanometra indica (Smith)	16				
Stephanometra spicata (Carpenter)	31	2/1 (2)	3.2	2/2 (1)	6.5
Stephanometra tenuipinna (Hartlaub)	2				
Dichrometra spp.	18	2/1(2)	5.6		
Family Colobometridae					
Cenometra bella (Hartlaub)	2				
Colobometra perspinosa (Carpenter)	2				
Pontiometra andersoni (Carpenter)	1				
Family Tropiometridae					
Tropiometra afra macrodiscus (Hara)	34	1/1 (1)	3.0	5/5 (1)	15.2
Family Asterometridae					
Pterometra venusta A. H. Clark	3				
Family Antedonidae					
Dorometra nana (Hartlaub)	2				

observed on the galatheids. It would be of great interest to discover the reason(s) for this sex indeterminate form.

Possible breeding pairs

Heterosexual pairs of *G. amboinensis* have not been found on the hosts. In *G. inflata*, 26.3% of galatheid-associated crinoids (n = 57) held heterosexual pairs, each with a male and an ovigerous female with nearly all (except two) of the ovigerous females larger than their respective partners: in more detail, the pairs were found on 50.0 % of host *Comanthus parvicirrus* (n=20), and 33.3 % of host *Comaster schlegelii* (n=12) and 50 % of host *Phanogenia gracilis* (n = 2).

Potts (1915) reported that no pairs were observed. On the other hand, Zmarzly (1984) noted that 50 % of *Allogalathea elegans* found on *Comanthus bennetti* (= now *Oxycomanthus bennetti*) are male-female pairs. Pairs were also recorded for three deepwater species of the galatheidean genera *Uroptychus* and *Munidopsis* (see Rice & Miller, 1992): *Uroptychus capillatus* Benedict, 1902 on *Crinometra brevipinna* (Pourtalès), *Munidopsis abdominalis* (A. Milne Edwards, 1880) on *Cidaris blakei* (A. Agassiz), *M. alaminos* Pequegnat & Pequegnat, 1970 on *Mesothuria gargantua* Diechmann. All the females of the pairs were ovigerous. Permanent or semi-permanent breeding relationships, as suggested by Rice & Miller (1992), may be presumed for *G. inflata*, but the existence of solitary, non-paired symbionts suggests that new partnerships result from the recruitment individuals of the opposite sex or of sex indeterminate individuals including megalopae.

Galatheid males may have one of two mating strategies: either to guard females until they spawn or to search for other mates. Female attractiveness, to males, could be determined by whether she is about to moult or to release her current brood. Alternatively, females may have one of two spawning patterns: either to delay spawning after mating, thereby increasing the possibility of sperm competition, or to spawn immediately after mating, in which case there is no need for a male to wait around to ensure his paternity. One of the things that would help answer the above arguments would be to have information about the stage of development of each female's brood. If the eggs were in an advanced stage of development we would expect the female to be accompanied by a male, whereas if her eggs had only just been laid then we would expect her to be solitary because a male could spend time more profitably elsewhere. However, examination of the material of *G. inflata* reveals that the eggs carried by 11 females of 15 heterosexual pairs are light brown in the preservative, suggesting an early stage in development; those of the other four females are eyed. Eggs carried by one of three solitary ovigerous females are eyed, while those of the other two females are not. More data and direct behavioral observations are needed to resolve the mating strategies.

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