論文 Article

In-situ Observations of Symbionts on Medusae Occurring in Japan, Thailand, Indonesia and Malaysia

Susumu OHTSUKA[1], Yusuke KONDO[2], Yoichi SAKAI[1], Takeshi SHIMAZU[3], Michitaka SHIMOMURA[4], Tomoyuki KOMAI[5], Keisuke YANAGI[5], Toshihiko FUJITA[6], Jun NISHIKAWA[7], Hiroshi MIYAKE[8], B. A. VENMATHI MARAN[1], Akio GO[2], Kazumitsu NAGAGUCHI[2], Shuhei YAMAGUCHI[2], Chutiwan DECHSAKULWATANA[9], Khwanruan SRINUI[9], Sumaitt PUTCHAKARN[9], MULYADI[10], Nova MUJIONO[10], SUTOMO[11] and Fatimah Md. YUSOFF[12]

Abstract: During an ecological investigation on symbionts of medusae in Eastern and Southeastern Asian waters, seven species of hydro- and scypho-medusae were found to harbor a wide variety of invertebrates and fishes: the isopod *Idotea metallica* and the nudibranch *Fiona pinnata* on the chondrophoran *Vellela vellela*; the actiniarian *Peachia quinquecapitata* on the leptomedusa *Aequorea coerulescens*; the butterfish *Psenopsis anomala* and the hyperiid amphipod *Hyperia galba* associated with the semaestome *Chrysaora melanaster*; *H. galba* on the semaestome *Aurelia limbata*; metacercariae of three species found in the mesogloea of a semaestome, *Aurelia* sp.; the ophiuroid *Ophiocnemis marmorata*, the caridean shrimp *Latreutes* spp., and the shrimp scad *Alepes djedaba* on the rhizostome *Rhopilema hispidum*; the swimming crab *Charybdis feriata* and *A. djedaba* on the rhizostome *Versuriga anadyomene*. Juveniles of benthic organisms such as crabs and ophiuroids seem to become hitchhikers for dispersal, while juvenile fish utilize medusae as refugia against predation. Since the previous and present studies have shown that edible rhizostomes are associated with many kinds of symbionts, fisheries for these jellyfishes possibly hinder the recruitment of symbionts such as decapods, ophiuroids and fish.

Keywords: Anti-Predation, Dispersal, Host, Medusa, Rhizostome, Symbiont

Ⅰ. Introduction

A wide variety of symbiotic interactions are known between host medusae and other organisms ranging from protists to fish (Théodoridès, 1989; Martin and Kuck, 1991; Ohtsuka et al., 2000, 2009; Arai, 2001; Yasuda, 2003; Kitamura, 2004). These involve phoresy, parasitism, parasitoidism, predation and mutualism, although the exact degrees of their dependence on the hosts are little understood (e.g. Arai, 2001; Ohtsuka et al., 2009).

Recently mass occurrence of medusae has been observed frequently around the world oceans, supposedly due to eutrophication, to overfishing and to climate changes (e.g. Arai, 2001; Mills, 2001). It is likely that these phenomena have a substantial impact not only on food web structure but also on symbiotic relationships. For example, such blooms seem to enhance hatching of phoronts of the histophagous apostome ciliate *Vampyrophrya pelagica* Chatton and Lwoff that frequently parasitizes planktonic copepods in the coastal waters of the world, since one of the triggers to induce phoront

1 Graduate School of Biosphere Science, Hiroshima University
2 Faculty of Applied Biological Science, Hiroshima University
3 Nagano Prefectural College (formerly)
4 Kitakyushu Museum of Natural History and Human History
5 Natural History Museum and Institute, Chiba
6 National Museum of Nature and Science, Tokyo
7 Atmosphere and Ocean Research Institute, University of Tokyo
8 School of Marine Biosciences, Kitasato University
9 Institute of Marine Science, Burapha University
10 Division of Zoology, Research Center for Biology, LIPI
11 Research Center for Oceanography, LIPI
12 Universiti Putra Malaysia

excystation is predation of carnivores such as medusae on the parasitized prey copepods (see Grimes and Bradbury, 1992; Ohtsuka et al., 2004, 2009). On the other hand, some edible rhizostomes are commercially important, especially in Asian waters (Omori and Nakano, 2001). Symbionts on these medusae could be accidentally captured during fishing.

Information on associations between medusae and their symbionts is still fragmentary and should be recorded and dissimilated in order to understand their roles in the marine ecosystem. During our ecological surveys on medusae in Asian waters carried out since 2008, some symbionts were found on seven identified and one unidentified species of shallow-water hydro- and scypho-medusae. They are briefly described herein.

Ⅱ. Materials and methods

Collection sites and dates of host jellyfish captures are described under the headings for each host. Medusae were scooped with dip nets together with their symbionts in Japan, Thailand and Indonesia. Symbionts on edible jellyfish were observed *in-situ* at fishing ports in Thailand (Ang Sila, Sri Racha) and Malaysia (Kukup). Symbionts were preserved in 10% neutralized formalin/sea-water or 70% ethanol for identification.

Ⅲ. Results

1. Japan

***Velella velella* (Linnaeus)** (Chondrophora, Hydrozoa)

Locality and date: off Kuchinoerabu Island, Kagoshima (30°24.52′N, 130°08.54′E), 1050 (local time), 26 May 2009.

Symbionts: *Idotea metallica* Bosc (Isopoda, Crustacea) (Fig. 1A); *Fiona pinnata* (Eschscholtz) (Nudibranchia, Mollusca) (Fig. 1B).

Remarks. Off Kuchinoerabu Island in the warm Kuroshio current, an aggregation of neustonic and planktonic medusae and siphonophores such as *Velella velella*, *Porpita porpita* Müller, *Physalia physalis* Linnaeus and *Pelagia panopyra* Péron were encountered on 26 May 2009. Two species of symbionts were identified from *V. velella*. Some of the individuals of *V. velella* were parasitized by the isopod *Idotea metallica* (Fig. 1A) and/or the nudibranch *Fiona pinnata* (Fig. 1B).

All of the individuals of *I. metallica* examined in the present study were attached near the base of the sail of *V. velella* (Fig. 1A). The color of the body was metallic white-blue, although the body color is highly variable ranging from red-brown, pale grey-brown, dark brown to blue-black, which is controlled by the dermal chromatophores (Herring, 1969). The association of *I. metallica* with *V. velella* seems to be a facultative phoresy, because it has been found also from floating debris such as lump oil (Herring, 1969). The genus *Idotea* is an omnivore, feeding on fish, pontellid copepods, decapod larvae, radiolarians, other dead or drying individuals and algae (Herring, 1969). The body color is likely to play a role in antipredation from birds and protection against strong sunlight on the sea surface (Herring, 1969).

The color of the cerata of *F. pinnata* was light blue in the present specimens, although it individually varies from blue purple to brown due to their diets (Lalli and Gilmer, 1989). We observed four individuals of *F. pinnata* voraciously consuming all tissues of *V. velella* (float diameter ca. 3 cm) within 1 hour (Fig. 1B). Two spiraled egg masses were attached on the totally bare-of tissue float of the colony (arrows in Fig. 1B). Since Lalli and Gilmer (1989) observed most individuals of *F. pinnata* laying at least two egg masses on separate occasions, these two egg masses might have been laid by one individual. Lalli and Gilmer (1989) mentioned that *F. pinnata* was not associated with other neustonic hydrozoans such as *Porpita* and *Physalia*, which was confirmed also in the present study. Hence this interaction between *Velella* and *Fiona* may be regarded as host-specific parasitoidism. However, these nudibranchs are also reported to prey upon the stalked barnacle *Lepas anatifera* Linnaeus (Lalli and Gilmer, 1989).

***Aequorea coerulescens* Brandt** (Leptomedusae, Hydrozoa)

Locality and date: Ofunato Bay, Iwate Prefecture, 15 July 2009.

Symbionts: *Peachia quinquecapitata* McMurrich (Anthozoa) (Fig. 1C)

Remarks. The individual obtained in the present study was measured as follows (number of tentacles 12; height of column 6.7 mm; diameter of oral disc 2.7 mm; diameter of tentacle crown 3.5 mm; diameter of physa 1.6 mm). Uchida (1932) first reported the occurrence of *Peachia quinquecapitata* on the same leptomedusa from Mutsu Bay, northern Japan.

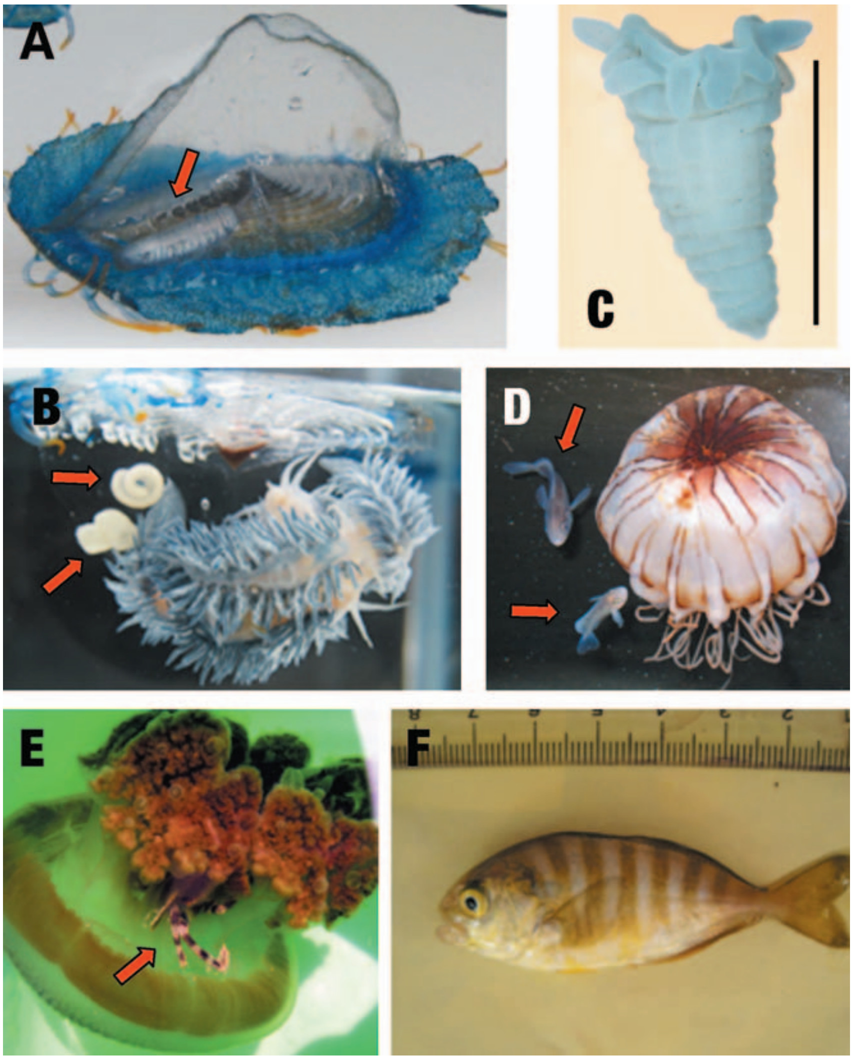

Fig. 1 Symbionts on *Velella velella* collected from off Kuchinoerabu Island, Japan (A, B); symbiont on *Aequorea coerulescens* collected from Ofunato Bay, Japan (C); fish juveniles associated with *Chrysaora melanaster* in the Seto Inland Sea, Japan (D); symbionts on *Versuriga anadyomene* collected from Pari Island, Indonesia (E, F). A. *Idotea metallica, in-situ*, arrowed; B. *Fiona pinnata, in-situ*, egg masses arrowed; C. *Peachia quinquecapitata* (scale: 5 mm); D. *Psenopsis anomala*, *in-situ*, arrowed; E. *Charybdis feriata*, *in-situ*, arrowed; F. *Alepes djedaba* (scale in mm).

***Chrysaora melanaster* (Brandt)** (Semaestomae, Scyphozoa)

Locality and date: off Takehara City, Seto Inland Sea (34°18′N, 132°55′E), daytime, 25 June 2009; Ofunato Bay, Iwate Prefecture, 19 April 2009.

Symbionts: *Psenopsis anomala* (Temminck and Schlegel) (Teleostomi) (Fig. 1D) (off Takehara City); *Hyperia galba* (Montagu) (Hyperiidea, Amphipoda) (Ofunato Bay)

Remarks. Two juveniles of *Psenopsis anomala* (Fig. 1D; total length 4.2, 6.2 cm) (Fig. 1D) were associated with one individual of *Chrysaora melanaster* (bell diameter 17.5 cm) collected from off Takehara City in the central part of the Seto Inland Sea. Larvae and juveniles of *Psenopsis anomala* are known to be associated with *Aurelia* sp., *Cyanaea nozakii* Kishinouye, *Nemopilema nomurai* Kishinouye and *C. melanaster* (Yasuda, 2003; Ohtsuka et al., 2009; present study). Yasuda (2003) has suggested that these stages of fish utilize medusae as a refuge from predators and as food sources (both medusa tissues and prey zooplankters gathered by the medusae).

Twenty-two juveniles of the hyperiid amphiphod *Hyperia galba* heavily parasitized a small individual of *C. melanaster* (bell diameter 28 mm) collected from Ofunato Bay, attaching to the subumbrellar surface and oral arms. This parasite is reported to exhibit a relatively low host-specificity, infecting not only a wide variety of medusae but also salps and ctenophores (Harbison et al., 1977).

***Aurelia limbata* (Brandt)** (Semaeostomae, Scyphozoa)

Locality and date: Sakihama Port, Okirai Bay, Iwate Prefecture, 8 April 2009.

Symbionts: *Hyperia galba* (Hyperiidea, Amphipoda)

Remarks. One mature female and two juveniles of *Hyperia galba* parasitized the bell of *Aurelia limbata* (bell diameter 146 mm).

***Aurelia* sp.** (or ***Aurelia aurita* (Linnaeus)** s. l.) (Semaeostomae, Scyphozoa)

Locality and date: off Takehara City, Seto Inland Sea (34°18′N, 132°55′E), 25 June 2009.

Symbionts: Metacercariae of *Opechona olssoni* (Yamaguti) (Fig. 2B,D) *Cephalolepidapedon saba* Yamaguti (Fig. 2E) and *Lepocreadium clavatum* (Ozaki) (Fig. 2C) (Trematoda, Platyhelminthes).

Remarks. Metacercariae of three species of lepocreadiid trematodes, *Opechona olssoni* (Fig. 2B,D), *Cephalolepidapedon saba* (Fig. 2E) and *Lepocreadium clavatum* (Fig. 2C), were found unencysted in the mesogloea of *Aurelia* sp. collected from the central part of the Seto Inland Sea on 25 June 2009 (Fig. 2A). Prevalence and intensity of metacercariae were 91.7% (N=12) and 1 to 352 individuals per host, respectively, although three trematode species were not distinguished.

These three trematodes proved for the first time to utilize *Aurelia* sp. as natural second intermediate hosts.

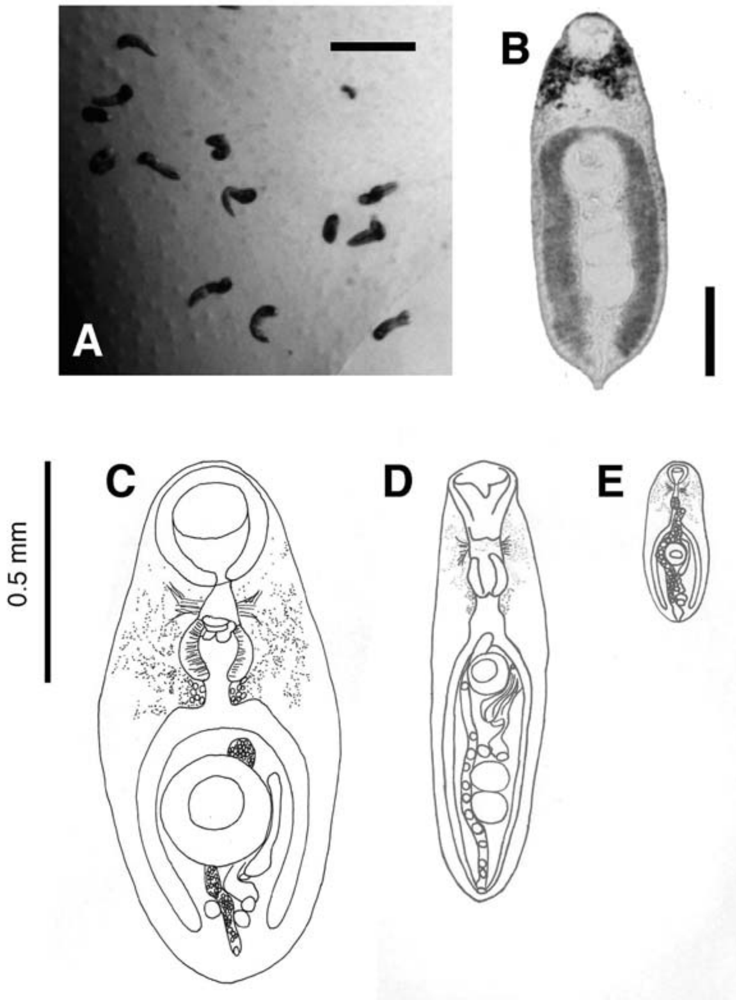

Fig. 2 Trematodes found in *Aurelia* sp. (A, C-E) and *Psenopsis anomala* (B) collected from the Seto Inland Sea, Japan. A. Metacercariae in the mesogloea of *Aurelia* sp. (scale: 1 mm); B. immature individual of *Opechona olssoni* found in the gut of *Psenopsis anomala*, ventral view (scale: 0.2 mm); metacercaria of C. *Lepocreadium clavatum*, ventral view; D. metacercaria of *Opechona olssoni*, ventral view; E. metacercaria of *Cephalolepidapedon saba*, ventral view (scale for C-E: 0.5 mm).

Since their adults are parasitic in the guts of fishes, medusivorous fish were collected from the neighboring waters, and their guts were examined for these endoparasitic trematodes. Adults of *Opechona olssoni* (Fig. 2B) and *Cephalolepidapedon saba* were obtained from the butterfish *Psenopsis anomala* (25 June 2009, associated with *Chrysaora melanaster*), while those of *Lepocreadium clavatum* occurred in the black scraper *Thamnaconus modestus* (Günther) (14 July 2009, collected with a trawl towed by a fisherman). These two fishes turned out to be their natural final hosts in the area off Takehara City. It is most likely that the three trematodes are transmitted from medusae to fish through predation of fish on medusae (e.g. Marcogliese , 1995, 2002; Purcell and Arai, 2001). None of their first intermediate hosts are as yet known.

2. Thailand

***Rhopilema hispidum* (Vanhöffen)** (Rhizostomae, Scyphozoa)

Locality and date: off Sichang Island, Gulf of Thailand (13°06.70′N, 100°48.54′E), 1045 (local time), 7 October 2009; Sri Racha and Ang Sila, Chonburi, 8 October 2009.

Symbionts: *Alepes djedaba* (Forsskål) (Teleostomi) (Fig. 3A, C) (off Sichang Island, Sri Racha); *Ophiocnemis marmorata* (Lamarck) (Ophiuroidea) (Fig. 3D) (Sri Racha, Ang Sila); *Latreutes* sp. aff. *anoplonyx* Kemp (Caridea, Decapod) (Fig. 3B) (off Sichang Island, Sri Racha). Ten specimens of *Ophiocnemis marmorata* were deposited at the National Museum of Natural History and Nature (registration numbers: Sri Racha, 2 specimens, NSMT E-6510; Ang Sila, 8 specimens, NSMT E-6511).

Remarks. One individual of *Rhopilema hispidum*

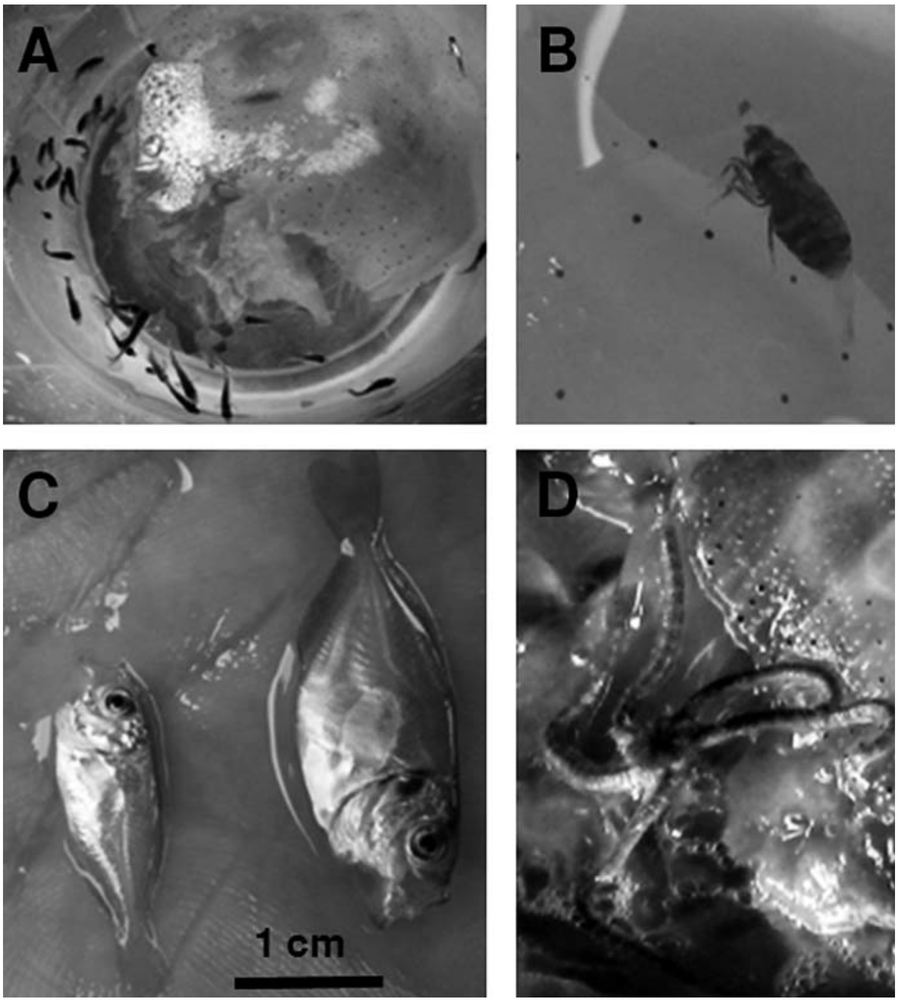

Fig. 3 Symbionts on *Rhopilema hispidum* collected from Sichang Island (A-C) and Sri Racha (D), Thailand. A. *Alepes djedaba* associated with medusa; B. *Latreutes* sp. aff. *anoplonyx* on medusa; C. *Alepes djedaba* ; D. *Ophiocnemis marmorata*.

(bell diameter 26 cm) was captured from off Sichang Island with a dip net of ca. 1 cm×1 cm mesh size. At least 43 individuals of *Alepes djedaba* (Fig. 3A, C) and 22 individuals of *Latreutes* sp. aff. *anoplonyx* (Fig. 3B) were associated with this individual. Some fish juveniles and possibly shrimps were escaped throughout the net mesh during collection, but most of them seemed to have penetrated into the interstices of the complex oral arms and umbrella and then to be collected together with the medusa.

The shrimp community on the medusa from Sichang Island was composed of 11 males (carapace length 3.2-3.6 mm) and 7 ovigerous (4.8-6.0 mm) and 4 non-ovigerous (1.8-4.0 mm) females. The association of *L. anoplonyx* with medusa is well known since it was reported by Kishinouye (1902), although the taxonomic problem may exist for the species (Komai, unpublished data). The host jellyfishes are: *Acromitus flagellatus* (Haeckel), *Mastigias papua* Linnaeus, *Nemopilema nomurai* (Kishinouye), *Rhizostoma* sp., *Rhopilema esculentum* Kishinouye and *R. hispidum* (Hayashi and Miyake, 1968; Hayashi et al., 2004; present study).

The juveniles of *A. djedaba* juveniles examined from Sichang Island ranged from 16.2 to 39.6 mm in total length (average ± standard deviation 25.9 ± 6.22 mm, N=43). On the eastern coast of the Mediterranean Sea, *A. djedaba* juveniles are reported to be associated with *Rhopilema nomadica* Galil, Spainer and Ferguson both of which are Lessepsian migrants through the Suez Canal (Spainer and Galil, 1991).

We visited two landing sites of edible jellyfishes (mainly *R. hispidum* with a small number of *Lobonemoides robustus* Stiasny) in the eastern part of the Gulf of Thailand (Ang Sila and Sri Racha, Chonburi) where we collected three symbionts, *Latreutes* aff. *anoplonyx*, juveniles of *Alepes djedaba* and *Ophiocnemis marmorata*.

The ophiuroids (Fig. 3D) collected from Sri Racha and Ang Sila measured 6.0, 6.9 mm in disc diameter (N=2) and 6.9-8.8 mm (N=8), respectively. Specimens of the ophiuroids associated with medusa are usually small-sized, falling within a diameter range of 6 to 12 mm (Fujita and Namikawa, 2006). Associations between the ophiuroid *O. marmorata* and some scyphomedusae have been reported repeatedly from India (host: *R. hispidum*), Mozambique (*R. nomadica*), Phillipines (*R. esculentum*), Australia (*Cephea cephea* (Forskål), *Netrostoma* sp.) and Japan (*R. esculentum*) (Fujita and Namikawa, 2006; Kanagaraj et al., 2008). This is the first record of an association in the waters of Thailand. However, the single individual of *R. hispidum* collected from Sichang Island on 7 October 2009 had no associated ophiuroid. It is likely that the association acts as a dispersal strategy for the ophiuroid (Fujita and Namikawa, 2006).

Fisheries targeting the edible rhizostome *R. hispidum* and others have been intensively carried out along the eastern and western coasts of the Gulf of Thailand (Nishikawa et al., unpublished). At the two landing sites of edible jellyfish in the eastern part of the Gulf of Thailand where we visited (Ang Sila and Sri Racha, Chonburi), the above-mentioned three symbionts were also observed together with landed jellyfish (Fig. 3D). These most likely had been accidentally captured during fishing.

***Rhopilema hispidum*?**

Locality and date: off Rad Island, Samae-sarn Islands, Gulf of Thailand (12°35.28′N, 100°58, 00′E), 14 November 2005.

Symbionts: unidentified ophiuroids (possibly *Ophiocnemis marmorata*) (Ophiuroidea) (Fig. 4).

Remarks. An association between a rhizostome host and heavily associated ophiuroids was recorded *in-situ* in underwater photos during a SCUBA dive, although these organisms were not identified exactly. The host and symbiont may be provisionally identified as *Rhopilema hispidum* and *Ophiocnemis marmorata*, respectively. This seems to be an extreme case in terms of the high abundance of the symbionts on the host medusa. At least 35 individuals were found from the oral arms of the host, suggesting either or both of the following possibilities: (1) medusae frequently migrate between the bottom habitat of ophiuroids and the water column, which enhances encounter rates for such symbioses; (2) this medusa happened to settle on an aggregation of ophiuroids at a restricted area on the sea-bottom.

3. Indonesia

***Versuriga anadyomene* (Maas)** (Rhizostomae, Scyphozoa)

Locality and date : off Pari Island, Java Sea (5°51′N, 106°36′E), 0740-0830 (local time), 7 November 2009.

Symbionts: *Charybdis feriata* (Linnaeus) (Brachyura,

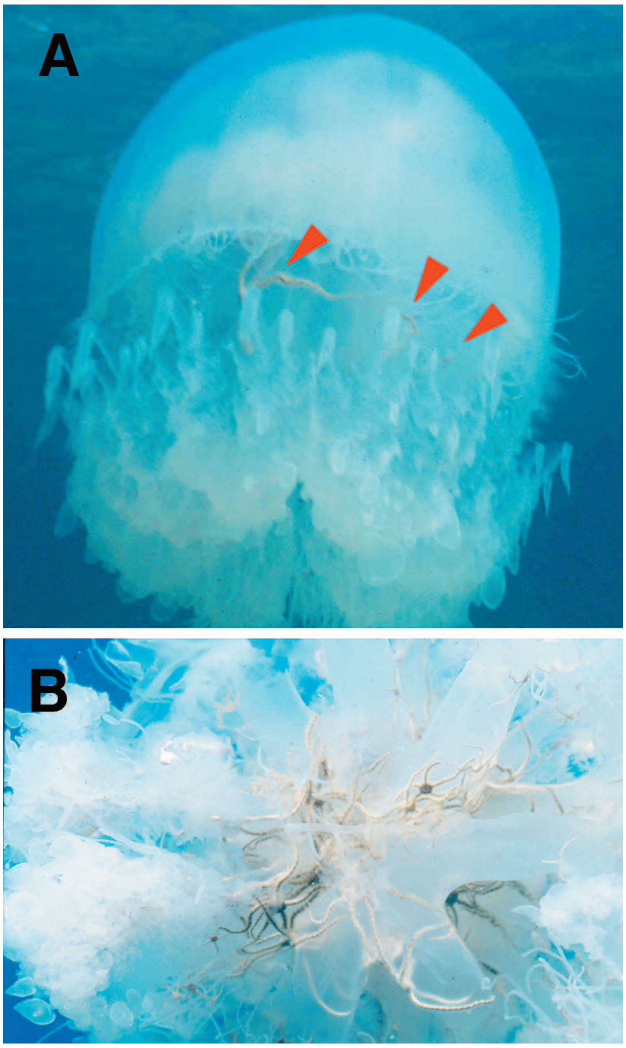

Fig. 4 Extremely dense aggregation of unidentified ophiuroids associated with unidentified rhizostome medusa (*Rhopilema hispidum*?) off Rad Island, Gulf of Thailand. A. Lateral view (ophiuroids arrowed); B. Ventral view.

Decapoda) (Fig. 1E); *Alepes djedaba* (Teleostomi) (Fig. 1F).

Remarks: The swimming crab *Charybdis feriata* has been frequently encountered as a symbiont on rhizostomes such as *Rhopilema esculentum*, *R. hispidum*, *Mastigias* sp., *Stomolophus meleagris* Agassiz, *Nemopilema nomurai* and *Versuriga anadyomene* in Asian waters (Suzuki, 1965; Towanda and Thuesen, 2006; Ohtsuka et al., 2009; present study). They usually hide between the oral arms (Fig. 1E, arrowed; see Ohtsuka et al., 2009, Fig. 5C also). Three of seven individuals of *V. anadyomene* (bell diameter 4.5 to 7.2 cm) had one accompanying crab each. One of them also harbored a juvenile of *Alepes djedaba* (Fig. 1F; total length 66.5 mm) as did *R. hispidum* occurring in the Gulf of Thailand. Including the results in Thailand, juveniles of the species associated with these rhizosotmes ranged from 16.2 to 66.5 mm in the maximum body dimension.

4. Malaysia

Rhopilema hispidum (Rhizostomae, Scyphozoa)

Locality and date: Kukup, Johhor, Malaysia (1° 19.99′N, 103°26.44′E), 17 March 2009.

Symbionts: *Ophiocnemis marmorata* (Ophiuroidea) (Fig. 5A); *Latreutes anoplonyx* Kemp (Caridea, Decapod) (Fig. 5B); *Sardinella melanura* (Cuvier) (?) (Fig. 5B) and a juvenile of an unidentified species belonging to the family Carangidae (Teleostomi) (Fig. 5B).

Remarks. The host medusae were also observed at a landing site at Kukup, Johhor, Malaysia on 17 March 2009. Associated shrimps (Fig. 5B) and ophiuroids (Fig.

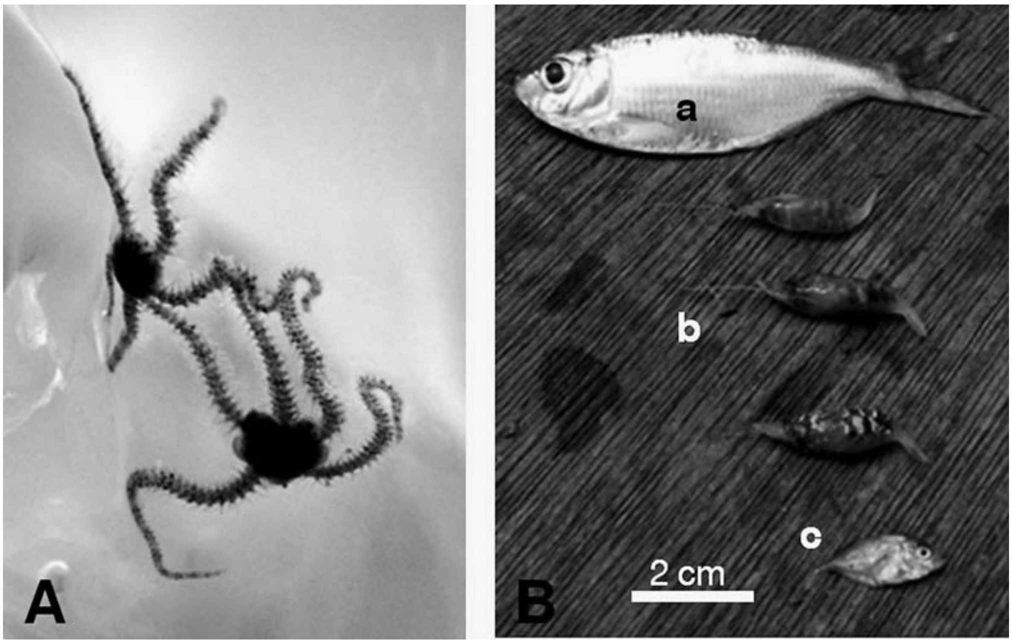

Fig. 5 Symbionts on *Rhopilema hispidum* collected from Kukup, Johhor, Malaysia. A. *Ophiocnemis marmorata*; B. *Sardinella melanura* (a), *Latreutes anoplonyx* (b), juvenile of unidentified species belonging to the family Carangidae (c).

5A) were found from oral arms or scapulets of the hosts. Although *Sardinella melanura* and carangid juveniles (Fig. 5B) were captured with the medusae from the fisheries ground, it is unknown whether they were closely associated with the medusae.

Ⅳ. Discussion

Actual interactions between host medusae and their symbionts are little understood except for some excellent works in the field and various laboratories (e.g. Marliave and Mills, 1993; Towanda and Thuesen, 2006; Lynam and Brierley, 2007; Masuda et al., 2008). These relationships may be basically classified into five categories: phoresy, commensalism, parasitism, parasitoidism and predation. Mutualism has rarely been reported regarding associations between medusae and symbionts (Ohtsuka et al., 2009).

A wide variety of benthic organisms are associated with medusae (Ohtsuka et al., 2009). These associations are usually regarded as obligate or facultative commensalism for antipredation and energy-saving dispersal and as a food source (Marliave and Mills, 1993; Towanda and Thuesen, 2006). Relationships between host medusae and the symbiont cancrid crab *Metacarcinus gracilis* (Dana) exhibit changes in symbiosis through ontogenetic development from megalopa larvae (primary kleptoparasite) to juveniles (facultative cleaning associate) (Towanda and Thuesen, 2006, as *Cancer gracilis*). In contrast, the association of species of *Latreutes* with medusae seems to be specific to reproductive activities on the basis of developmental composition and maturity on the host (Hayashi et al., 2004; present study). *Ophiocnemis marmorata* is a highly unique ophiuroid utilizing medusae presumably for dispersal. In ophiuorids a variety of embryonic development patterns ranging indirect to direct development are known (Hendler, 1988). Although the life cycle of *O. marmorata* is not as yet known, it may exhibit an association of juveniles with medusae to compensate for the weak dispersal ability of larval stages.

Recent studies on the associations between fish juveniles and medusae strongly support a hypothesis that medusa-associated fish juveniles are protected from predation (Brodeur, 1998; Purcell and Arai, 2001; Bonaldo et al., 2004; Lynam and Brierley, 2007; Masuda et al., 2008; Ohtsuka et al., 2009; present study). We also made an *in-situ* observation of fish juveniles associated with *Chrysaora*, *Cyanea, Versuriga* and *Rhopilema* in Japan, Thailand and Indonesia. These did not detach themselves from the hosts until just before the latter were scooped into the air with dip nets. Lynam and Brierley (2007) have found on the basis of a long-term survey in the

North Sea that residual survival of 0-group whiting *Merlangius merlangus* (Linnaeus) was significantly positively correlated with the abundance of *Cyanea* spp. On the other hand, such a tendency was not detected between other gadoid juveniles and *Cyanea* spp. (Lynam and Brierley, 2007). However, some fish juveniles take advantage of medusae in another way through association. Gut content analysis of young *Psenopsis anomala* associated with *Chrysaora melanaster* in the Seto Inland Sea revealed the presence of unidentified nematocysts in the gut, suggesting that the associate utilizes the host not only as a refuge but also as a food item (Ohtsuka et al., unpublished data).

Many medusae are intermediate or paratenic hosts for some helminth larvae (Marcogliese, 1995, 2002; Ohtsuka et al., unpublished data). Predation by associated fish on medusae may provoke transmission of helminth larvae to their final hosts (Marcogliese, 1995, 2002; Ohtsuka et al., 2009). Our present observation has revealed that *P. anomala* associated with *C. melanaster* was parasitized by adults of some trematodes, some of which may utilize *C. melanaster* as intermediate hosts.

Jellyfish fisheries are economically important in Southeastern Asia and China (Omori and Nakano, 2001). According to these authors, average annual catch of rhizostome jellyfish in these areas are approximately 321,000 metric tons in wet weight. Nishikawa et al. (2008) estimated that catches of edible jellyfish at Thanh Hoa, northern Vietnam are about 20,000 to 30,000 individuals per day or 800,000 to 1,200,000 individuals per fishery period. If associates with these medusae are accidentally captured by fisheries, recruitment and dispersal of benthic and nektonic symbionts might be greatly influenced by such anthropogenic activities in Asian waters. Incidence and abundance of symbionts on these edible medusae should be carefully surveyed in Asian fisheries grounds throughout the active fisheries periods.

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