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Sea Stars and Their Macrosymbionts in the Bay of Nhatrang, Southern Vietnam

T. I. Antokhina and T. A. Britayev

Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Leninskii pr. 33, Moscow, 119071 Russia
e-mail: tanya@sai.msu.ru

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Abstract—Shallow-water sea stars of the Bay of Nhatrang (Southern Vietnam) and their obligatory macrosymbionts are studied. A total of 39 sea star species of 13 families are recorded; 19 of them are new for the Vietnamese fauna. More than half of species (61.6%) belong to the families Oreasteridae and Ophidiasteridae. The fauna of obligatory macrosymbionts of sea stars of the Bay of Nhatrang includes 21 species (including one sedentary ctenophoran, five polychaetes, four mollusks, two shrimps, eight copepods, and one fish), 18 of which are recorded in Vietnam for the first time. The taxonomic composition of sea stars and fauna of their symbionts have shown a high species diversity of these groups in the Bay of Nhatrang compared to other regions.

Keywords: Echinodermata, sea stars, symbionts, Recent, Bay of Nhatrang, southern Vietnam

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INTRODUCTION

Sea stars are typical members of shallow-water tropical communities. Since most of them are active predators feeding on mollusks, crustaceans, coelenterates, and other invertebrates, they play an important role in coral reef ecosystems. In addition, some sea star species (for example, *Acanthaster planci* and *Culcita novaeguineae*) consume scleractinian corals, directly affecting the condition of coral reefs, species composition, population structure, and distribution of corals.

To date, many works have been devoted to the study of sea star biodiversity in the South China Sea (Ming-Shiou Jeng, 1998; Lane, 2000; Ho, 2002; Purwati and Lane, 2004; etc.). However, the sea star fauna of Vietnam, in particular, the Bay of Nhatrang (Khanh Hoa Province), is poorly understood. Dawydoff (1952) was the first to investigate sea stars and other invertebrates of Vietnam. Subsequent surveys of the sea star fauna of Vietnam appeared as late as the 1990s (Ho, 1994, 2001, 2002; Fjukmoen, 2006). However, in our opinion, the number of species (23) listed by Ho (2002) does not correspond to the actual sea star diversity in the Bay of Nhatrang, and Vietnam as a whole.

Sea stars are frequently inhabited by symbiotic animals of various taxonomic groups, ranging from protists to fish (Jangoux, 1990). To date, the fauna of symbionts of sea stars of the northeastern Atlantic is relatively thoroughly examined (Barel and Kramers, 1977). Individual studies describe obligatory symbionts of sea stars of the tropical Indo-West Pacific (Pettibone, 1969; Humes, 1976; Hartmann-Schroder, 1981; Bruce, 1982; Waren, 1983). At the same time, the data on symbionts of sea stars of the coast of Vietnam are restricted to the find of a new polynoid species in *Culcita novaeguineae*, *Protoreaster nodosus*, and *Linckia laevigata* (Britayev, 2005).

Sea stars are frequently well preserved in the fossil record. Moreover, some symbiotic species produce distinct traces on the sea star surface, which are observed in fossil specimens. In this connection, the present study is of interest for paleontologists.

The purpose of this work is to study the fauna of sea stars and their macrosymbionts in the Bay of Nhatrang. The majority of species considered in this work are ectosymbionts. The mollusks *Stylifer* spp., which are sometimes completely immersed in the host tissue, and the fish *Carapus mourlani*, which inhabits the body cavity of sea stars in the daytime and leave the host at night, are tentatively assigned to endosymbionts.

MATERIAL AND METHODS

The material was collected in the Bay of Nhatrang (southern Vietnam) from April to June, 2006, 2007, and 2008 near Do, Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands (Fig. 1).

Sea stars were collected using snorkelling and scuba-diving at 2–35 m of depth. To prevent the loss of symbionts, specimens under water were placed in

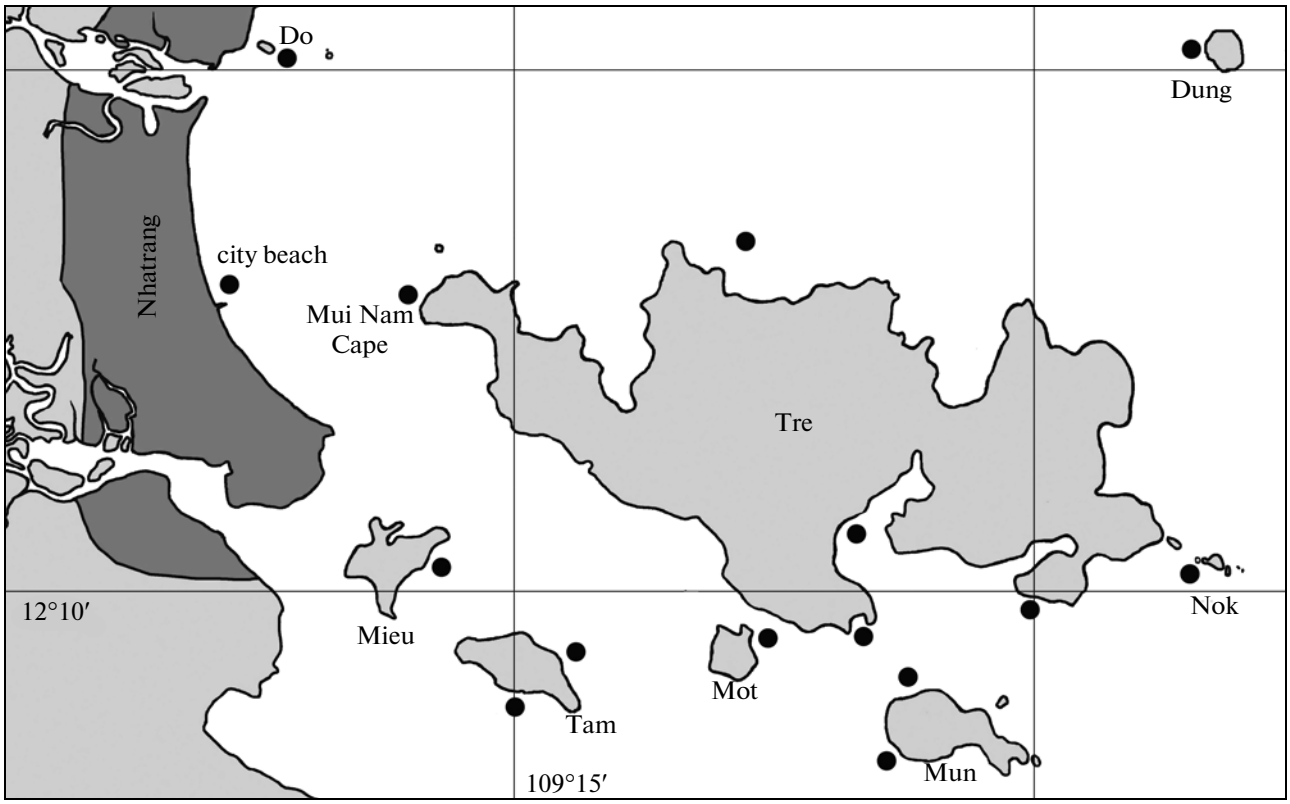


Fig. 1. Map of the Bay of Nhatrang, sampling places are marked by points.

plastic bags and transported to the surface. As sea stars were collected, the localization of symbionts on the host surface was recorded under water. On the boat, the radius of each sea star was measured, the surface was thoroughly examined to collect symbionts, and treated with a weak alcohol solution. Subsequently, sea stars were dissected to collect polychaetes, fishes, and gastropods. The specimens collected (except for fishes) were fixed with 70° alcohol. The fishes *Carapus mourlani* (Petit, 1934) were fixed with 10% formalin and, then, transferred to 70° ethyl alcohol.

A total of about 400 sea star specimens were collected; however, the majority of species are represented in our material by one or two specimens. The only mass species in our material was the sea star *Culcita novaeguineae* (205 specimens). They have provided 507 symbionts (excluding copepods). In addition, we obtained washouts from 13 specimens of *Acanthaster planci*, 8 of *Linckia laevigata*, and 1–4 specimens of *Choriaster granulatus, Echinaster lusonicus, Nardoa frianti, Eureaster insignis, Halityle regularis, Protoreaster nodosus, Pentaceraster regulus*, and *Luidia maculata.*

Sea star species and their symbionts recorded for the first time at the coast of Vietnam are marked below by an asterisk. Sea star species recorded for the first time as the hosts of symbionts are marked by two asterisks.

RESULTS

Sea Star Fauna

CLASS ASTEROIDEA

Family Luidiidae

***Luidia maculata* Müller et Troschel, 1842**

Plate 6, fig. 1

Locality in the bay: Tre and Tam islands.

Substrate: silty sand. Depth: 15–35 m.

Distribution: tropical Indo-West Pacific, including the Red Sea.

Symbionts: *Pottsiscalisetosus praelongus* and *Ophiodromus* sp.

Luidia savignyi* (Audouin, 1826)

Plate 6, fig. 2

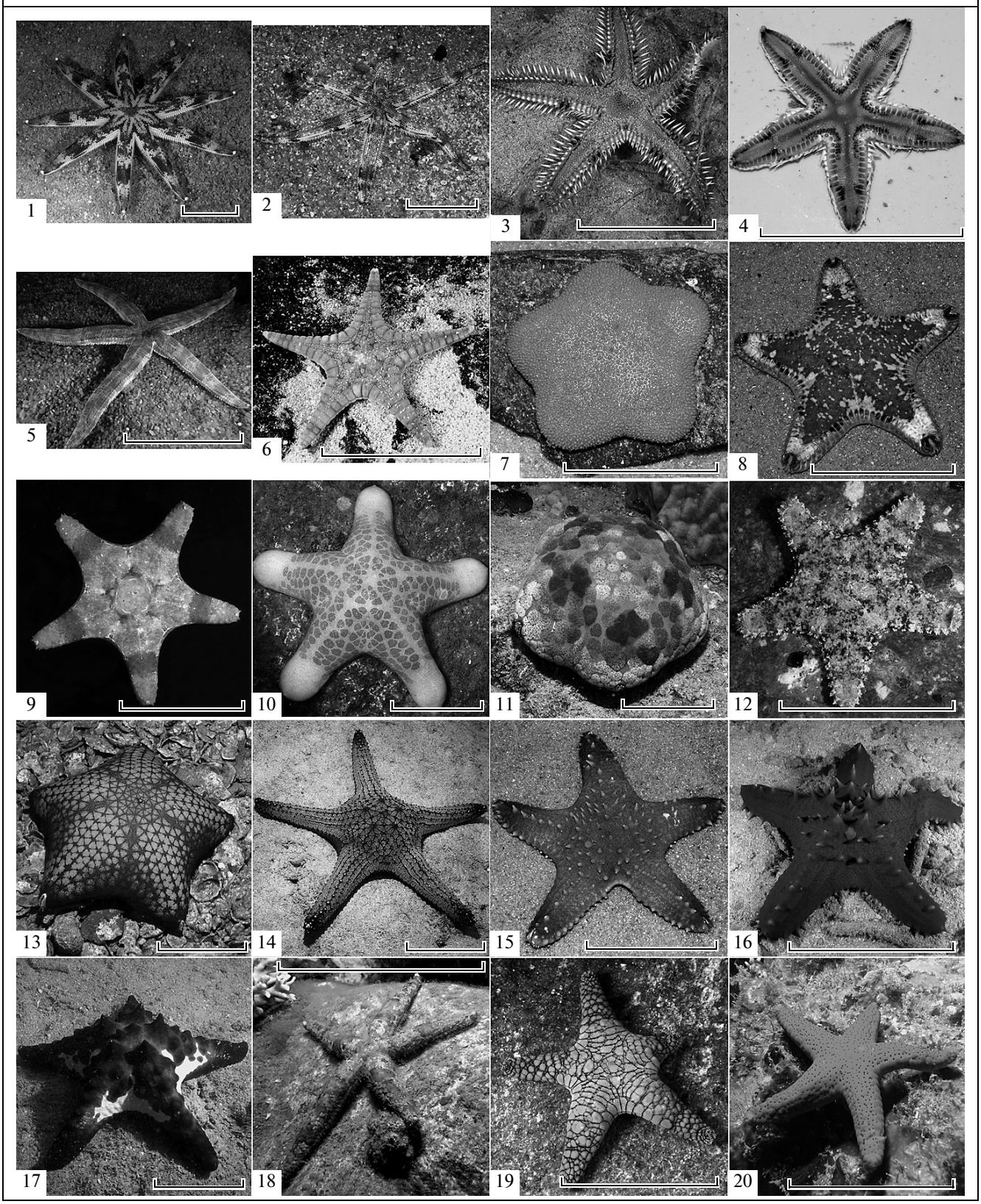
Locality in the bay: Mun Island.

Substrate: silty sand. Depth: 30 m.

Distribution: Indo-West Pacific–Aldabra Islands, East Africa and Madagascar, Mauritius Island, New Caledonia, Red Sea, Seychelles, South Africa, Tanzania, Ceylon, Bay of Bengal, South China Sea, and Philippines.

Symbionts: not recorded.

Plate 6



Explanation of Plate 6

Figs. 1–20. (1) *Luidia maculata*, (2) *Luidia savignyi*, (3) *Astropecten polyacanthus*, (4) *Astropecten* sp., (5) *Archaster angulatus*, (6) *Stellaster equestris*, (7) *Asterodiscides elegans*, (8) *Anthenea aspera*, (9) *Bothriaster primigenius*, (10) *Choriaster granulatus*, (11) *Culcita novaeguineae*, (12) *Gymnanthenea laevis*, (13) *Halityle regularis*, (14) *Pentaceraster regulus*, (15) *Pentaceraster* sp. 1, (16) *Pentaceraster* sp. 2, (17) *Protoreaster nodosus*, (18) *Cistina columbiae*, (19) *Fromia indica*, (20) *Fromia milleporella*. Scale bars: (1–8, 10–17) 10 cm, (9, 18) 5 cm, and (19, 20) 3 cm.

Family Astropectinidae

***Astropecten polyacanthus* Müller et Troschel, 1842**

Plate 6, fig. 3

Locality in the bay: city beach, Tre Island (Mui Nam Cape).

Substrate: silty sand. Depth: 10 m.

Distribution: Indo-West Pacific–Red Sea, Zanzibar, Mozambique, Mauritius Island, Seychelles, Ceylon, Andaman Islands, Maldives, Mergui Archipelago, Hongkong, China, Taiwan, South China Sea, Philippines, India, Sulu Archipelago, Fiji Archipelago, Admiralty, Australia, Japan, Samoan, Hawaii, and Cook Strait.

Symbionts: not recorded.

***Astropecten* sp.**

Plate 6, fig. 4

Locality in the bay: city beach, Tre Island (Mui Nam Cape).

Substrate: silty sand. Depth: 10 m.

Symbionts: not recorded.

Family Archasteridae

Archaster angulatus* Müller et Troschel, 1842*

Plate 6, fig. 5

Locality in the bay: Tre Island (Mui Nam Cape).

Substrate: silty sand. Depth: 5–10 m.

Distribution: East Africa, Madagascar, Mauritius Island, Mozambique, Red Sea, Indian Ocean, South China Sea, Japan, and Australia.

Symbionts: *Ophiodromus* sp. and *Carapus mourlani*.

Family Goniasteridae

***Stellaster equestris* (Retzius, 1805)**

Plate 6, fig. 6

Locality in the bay: Mot Island.

Substrate: dead coral reef. Depth: 5–10 m.

Distribution: Indo-West Pacific–East Africa, Madagascar, Mozambique, Red Sea, Persian Gulf, Ceylon, Bay of Bengal, eastern India, Korea, South China Sea, Philippines, Japan, and Australia.

Symbionts: not recorded.

Family Asterodiscididae

Asterodiscides elegans* (Gray, 1847)

Plate 6, fig. 7

Locality in the bay: Dung Island.

Substrate: silty sand. Depth: 12–20 m.

Distribution: tropical Indo-West Pacific.

Symbionts: not recorded.

Family Oreasteridae

Anthenea aspera* Doderlein, 1915

Plate 6, fig. 8

Locality in the bay: Dung Island.

Substrate: silty sand. Depth: 12 m.

Distribution: western Pacific Ocean, including Australia, China, South China Sea, Hongkong, and Japan.

Symbionts: not recorded.

Bothriaster primigenius* Doderlein, 1916

Plate 6, fig. 9

Locality in the bay: Mun Island.

Substrate: coral reef. Depth: 4 m.

Distribution: tropical Indo-West Pacific.

Symbionts: not recorded.

Choriaster granulatus* Lütken, 1869*

Plate 6, fig. 10

Locality in the bay: Mun, Mot, and Dung islands.

Substrate: coral reef, boulders. Depth: 10–30 m.

Distribution: Indo-West Pacific–Western Africa, Red Sea, Maldives, South China Sea, Australia, and southern islands of the Pacific Ocean.

Symbionts: *Asterophylia culcitae, Hololepidella millari*, and *Periclimenes soror*.

Culcita novaeguineae* Müller et Troschel, 1842*

Plate 6, fig. 11

Locality in the bay: Do, Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Substrate: coral reef, boulders. Depth: 3–20 m.

Distribution: western Pacific Ocean, including New Guinea, South China Sea, Andaman islands, and Australia.

Symbionts: *Asterophylia culcitae, Hololepidella laingensis, Hololepidella millari, Stilifer* sp. 1, *Periclimenes soror*, and *Carapus mourlani*.

Gymnanthenea laevis* H.L. Clark, 1938

Plate 6, fig. 12

Locality in the bay: Mot Island.

Substrate: dead coral reef. Depth: 5–10 m.

Distribution: tropical Indo-West Pacific.

Symbionts: not recorded.

Halityle regularis* Fisher, 1913*

Plate 6, fig. 13

Locality in the bay: Dung Island.

Substrate: silty sand. Depth: 10–20 m.

Distribution: tropical Indo-West Pacific.

Symbionts: *Periclimenes soror*, and *Hololepidella millari*.

Pentaceraster regulus* (Müller et Troschel, 1842)

Plate 6, fig. 14

Locality in the bay: Dung Island.

Substrate: silty sand. Depth: 10–20 m.

Distribution: Indo-West Pacific–Red Sea, western Indian Ocean, Bay of Bengal, South China Sea, Philippines, southern Japan, northern Australia, and New Caledonia.

Symbionts: *Periclimenes soror*.

***Pentaceraster* sp. 1**

Plate 6, fig. 15

Locality in the bay: Dung Island.

Substrate: silty sand. Depth: 10–20 m.

Symbionts: not recorded.

***Pentaceraster* sp. 2**

Plate 6, fig. 16

Locality in the bay: Dung Island.

Substrate: silty sand. Depth: 10–20 m.

Symbionts: not recorded.

Protoreaster nodosus* (Linnaeus, 1758)*

Plate 6, fig. 17

Locality in the bay: Dung Island and Tre Island (Mui Nam Cape)

Substrate: silty sand. Depth: 10–20 m.

Distribution: Indo-West Pacific–East Africa, Madagascar, Kenya, Seychelles, Tanzania, Ceylon, South China Sea, Philippines, Guam, New Caledonia, Palau Islands, and Australia.

Symbionts: *Periclimenes soror, Hololepidella millari*, and *Coeloplana astericola*.

Family Ophidiasteridae

Cistina columbiae* Gray, 1840

Plate 6, fig. 18

Locality in the bay: Mot Island.

Substrate: dead coral reef. Depth: 5–10 m.

Distribution: Chagos Archipelago, Mauritius Island, Maldives, South China Sea, Japan, and New Caledonia.

Symbionts: not recorded.

Fromia indica* (Perrier, 1869)

Plate 6, fig. 19

Locality in the bay: Mot, Nok, and Dung islands.

Substrate: coral reef, boulders. Depth: 5–25 m.

Distribution: Bay of Bengal, South China Sea, Indonesia, southern Japan, Fiji, and New Caledonia.

Symbionts: not recorded.

***Fromia milleporella* (Lamarck, 1816)**

Plate 6, fig. 20

Locality in the bay: Mot, Nok, and Dung islands.

Substrate: coral reef, boulders. Depth: 5–25 m.

Distribution: tropical Indo-West Pacific.

Symbionts: not recorded.

***Fromia monilis* (Perrier, 1869)**

Plate 7, fig. 21

Locality in the bay: Mot, Nok, and Dung islands.

Substrate: coral reef, boulders. Depth: 5–25 m.

Distribution: Indo-West Pacific–Red Sea, Andaman Islands, South China Sea, Indonesia, southern Japan, northwestern Australia, New Caledonia, and Caroline Islands.

Symbionts: *Asterophylia culcitae*.

Leiaster leachi* (Gray, 1840)

Plate 7, fig. 22

Locality in the bay: Mot Island.

Substrate: silty sand. Depth: 10–20 m.

Distribution: Aldabra, East Africa, Mauritius Island, Mozambique, Red Sea, western Indian Ocean, and South China Sea.

Symbionts: not recorded.

Leiaster speciosus* von Martens, 1866

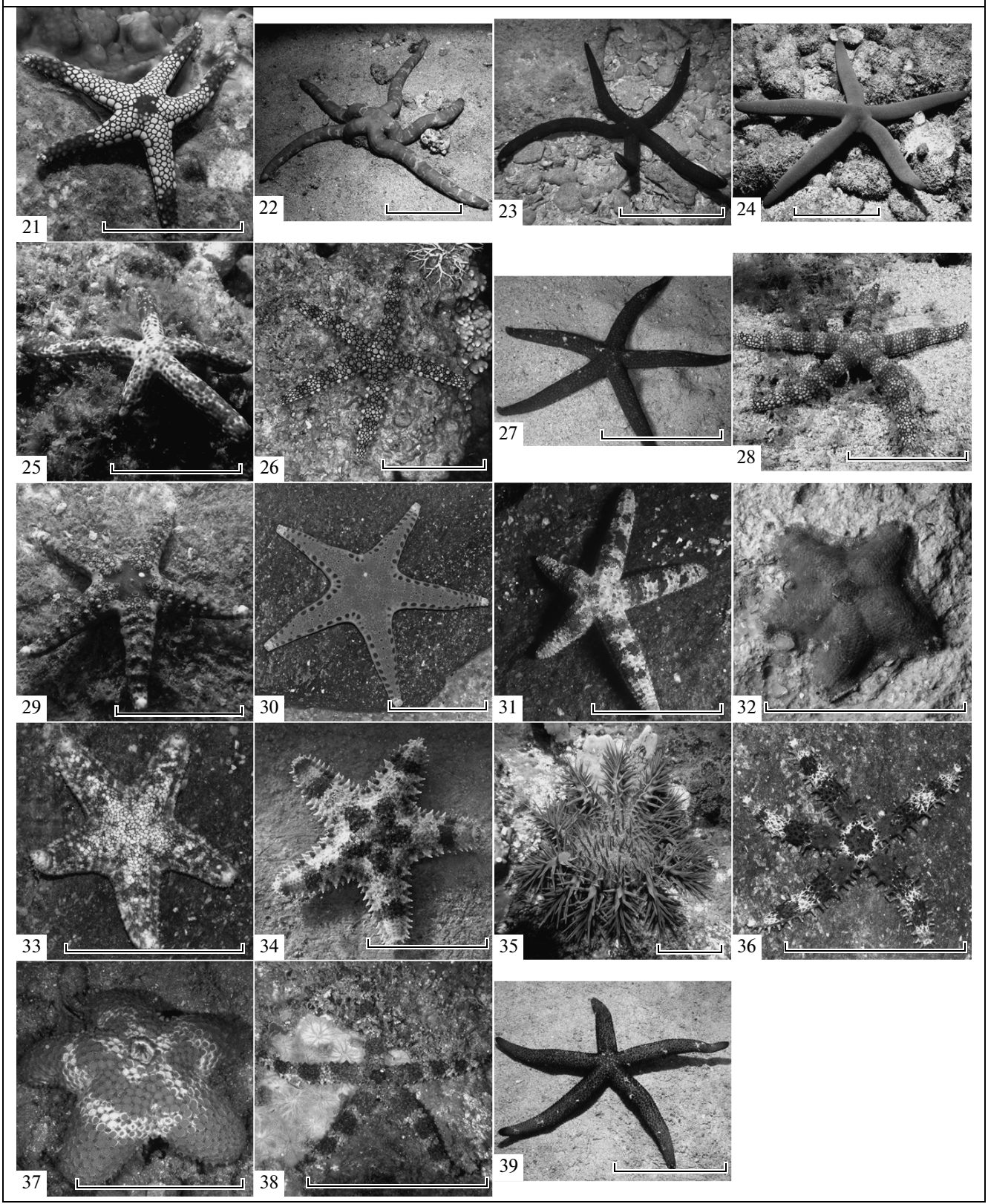
Plate 7, fig. 23

Locality in the bay: Mot Island.

Explanation of Plate 7

Figs. 21–39. (21) *Fromia monilis*, (22) *Leiaster leachi*, (23) *Leiaster speciosus*, (24) *Linckia laevigata*, (25) *Linckia multifora*, (26) *Nardoa frianti*, (27) *Nardoa galatheae*, (28) *Nardoa tuberculata*, (29) *Neoferdina cumingi*, (30) *Neoferdina* sp., (31) *Ophidiaster granifer*, (32) *Aquilonastra cepheus*, (33) *Tegulaster ceylanica*, (34) *Valvaster striatus*, (35) *Acanthaster planci*, (36) *Mithrodia clavigera*, (37) *Euretaster insignis*, (38) *Echinaster callosus*, and (39) *Echinaster luzonicus*. Scale bars: (21, 31–33, 34) 3 cm, (22–24, 26–28, 35–38) 10 cm, and (25, 29, 30, 39) 5 cm.

Plate 7



Substrate: coral reef, boulders. Depth: 10–20 m.

Distribution: Indonesia, South China Sea, Philippines, Ryukyu Islands, eastern Australia, Lord Hau Island, and New Caledonia.

Symbionts: not recorded.

Linckia laevigata* (Linnaeus, 1758)*

Plate 7, fig. 24

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Substrate: coral reef, rock. Depth: 3–20 m.

Distribution: Indo-West Pacific–East Africa, Mozambique, Zanzibar, Red Sea, Persian Gulf, Maldives, Madras, Andaman Islands, South China Sea, Philippines, Celebes, Flores Island, Timor, Ambon Island, New Guinea, New Caledonia, Guam, Caroline Islands, Fiji, Samoan, Hawaiian Islands, and Australia.

Symbionts: *Asterophylia culcitae, Hololepidella laingensis, Hololepidella millari, Stilifer* sp. 2, *Periclimenes soror*, and *Carapus mourlani*.

***Linckia multifora* (Lamarck, 1816)**

Plate 7, fig. 25

Locality in the bay: Mot and Nok islands.

Substrate: coral reef, rock. Depth: 5–25 m.

Distribution: tropical Indo-West Pacific–Red Sea, Mozambique, Mauritius Island, Madagascar, Seychelles, Maldives, Sri Lanka, Ceylon, Andaman Islands, Maldives, Christmas Island, South China Sea, Philippines, Hongkong, Japan, Sulawesi, Amboina Island, Australia, New Caledonia, Micronesians, Fiji, Samoan, Society Islands, and Hawaiian Islands.

Symbionts: not recorded.

Nardoa frianti* Koehler, 1910*

Plate 7, fig. 26

Locality in the bay: Mot, Nok, and Tre islands.

Substrate: coral reef, boulders. Depth: 5–20 m.

Distribution: Andaman Islands, South China Sea, Philippines, Caroline Islands, and New Caledonia.

Symbionts: *Granulithyca nardoafrianti*, and *Periclimenes soror.*

Nardoa galatheae* (Lütken, 1865)

Plate 7, fig. 27

Locality in the bay: Mot, Nok, Tre, and Mun islands.

Substrate: coral reef, boulders. Depth: 5–20 m.

Distribution: tropical Indo-West Pacific.

Symbionts: not recorded.

***Nardoa tuberculata* Gray, 1840**

Plate 7, fig. 28

Locality in the bay: Mot and Nok islands.

Substrate: coral reef, boulders. Depth: 5–20 m.

Distribution: South China Sea, Philippines, southern Japan, and Australia.

Symbionts: not recorded.

Neoferdina cumingi* Gray, 1840

Plate 7, fig. 29

Locality in the bay: Nok Island.

Substrate: rocks. Depth: 15 m.

Distribution: South China Sea, Japan, Australia, New Caledonia, and Papua New Guinea.

Symbionts: not recorded.

***Neoferdina* sp.**

Plate 7, fig. 30

Locality in the bay: Mot Island.

Substrate: coral reef, boulders. Depth: 5 m.

Symbionts: not recorded.

Ophidiaster granifer* Lütken, 1871

Plate 7, fig. 31

Locality in the bay: Mot Island.

Substrate: coral reef, boulders. Depth: 5–10 m.

Distribution: South China Sea, Indonesia, northern Australia, New Caledonia, and Tonga Islands.

Symbionts: not recorded.

Family Asterinidae

Aquilonastra cepheus* (Müller et Troschel, 1842)

Plate 7, fig. 32

Locality in the bay: Mot Island.

Substrate: coral reef, boulders. Depth: 5–10 m.

Distribution: South China Sea.

Symbionts: not recorded.

Tegulaster ceylanica* (Doderlein, 1888)

Plate 7, fig. 33

Locality in the bay: Mot Island.

Substrate: coral reef, boulders. Depth: 5–10 m.

Distribution: South China Sea.

Symbionts: not recorded.

Family Asteropseidae

Valvaster striatus* (Lamarck, 1816)

Plate 7, fig. 34

Locality in the bay: Mot Island.

Substrate: coral reef, boulders. Depth: 5–10 m.

Distribution: Mauritius Island, Bay of Bengal, South China Sea, Philippines, Australia, Hawaiian Islands, and New Caledonia.

Symbionts: not recorded.

Family Acanthasteridae

Acanthaster planci* (Linnaeus, 1758)*

Plate 7, fig. 35

Locality in the bay: Tre, Mot, Mun, Nok, Dung islands.

Substrate: coral reef. Depth: 5–20 m.

Distribution: tropical Indo-West Pacific.

Symbionts: *Hololepidella laingensis, Hololepidella millari*, and *Periclimenes soror.*

Family Mithrodiidae

Mithrodia clavigera* (Lamarck, 1816)

Plate 7, fig. 36

Locality in the bay: Mot and Dung islands.

Substrate: coral reef. Depth: 5–20 m.

Distribution: Bahama Islands, Caribbean Sea, East Africa, Madagascar, Red Sea, Seychelles, Aldabra Islands, South China Sea, New Caledonia, and Palau Islands.

Symbionts: not recorded.

Family Pterasteridae

Euretaster insignis* (Sladen, 1882)*

Plate 7, fig. 37

Locality in the bay: Mot and Mun islands.

Substrate: silty sand. Depth: 15–30 m.

Distribution: eastern India, Malaysia, South China Sea, Philippines, Australia, and Samoan.

Symbionts: *Asterophylia culcitae, Hololepidella millari, Periclimenes soror*, and *Periclimenes imperator.*

Family Echinasteridae

Echinaster callosus* Marenzeller, 1895

Plate 7, fig. 38

Locality in the bay: Nok Island.

Substrate: coral reef, boulders. Depth: 5–20 m.

Distribution: tropical Indo-West Pacific, from East Africa to Japan and New Caledonia.

Symbionts: not recorded.

Echinaster luzonicus* (Gray, 1840)*

Plate 7, fig. 39

Locality in the bay: Nok Island and Dung islands.

Substrate: coral reef, boulders. Depth: 5–20 m.

Distribution: Maldives, western India, Bay of Bengal, South China Sea, northern Australia, and Caroline Islands.

Symbionts: *Asterophylia culcitae, Periclimenes soror, Stellicola oreastriphilus*, *Doridicola echinasteris*, and *Coeloplana astericola.*

Fauna of Sea Star Macrosymbionts

P h y l u m Ctenophora

Coeloplana astericola* Mortensen 1927

Plate 8, fig. 11

Locality in the bay: Nok Island and Tre Island (Mui Nam Cape).

Depth: 6–20 m.

Distribution: tropical eastern Pacific.

Hosts: *Echinaster luzonicus*, and *Protoreaster nodosus.*

P h y l u m Annelida

CLASS POLYCHAETA

Family Polynoidae

***Asterophylia culcitae* Britayev, 2005**

Plate 8, fig. 9

Locality in the bay: Mot and Nok islands.

Depth: 3–20 m.

Distribution: South China Sea.

Hosts: *Choriaster granulatus, Culcita novaeguineae, Protoreaster nodosus, Linckia laevigata, Fromia monilis, Echinaster luzonicus*, and *Eureaster insignis.*

Hololepidella laingensis* Britayev, Doignon et Eeckhaut, 1999

Plate 8, fig. 2

Locality in the bay: Mieu, Tam, Mot, Mun, Nok, Dung islands.

Depth: 3–20 m.

Distribution: Papua New Guinea and South China Sea.

Hosts: *Acanthaster planci, Culcita novaeguineae*, and *Linckia laevigata.*

Hololepidella millari* Britayev, Doignon et Eeckhaut, 1999

Plate 8, fig. 1

Locality in the bay: Mot Island.

Depth: 3–20 m.

Distribution: Papua New Guinea and South China Sea.

Hosts: *Acanthaster planci, Choriaster granulatus, Culcita novaeguineae, Halityle regularis, Protoreaster nodosus, Linckia laevigata*, and *Eureaster insignis.*

Pottsiscalisetosus praelongus* (Marenzeller, 1902)

Plate 8, fig. 3

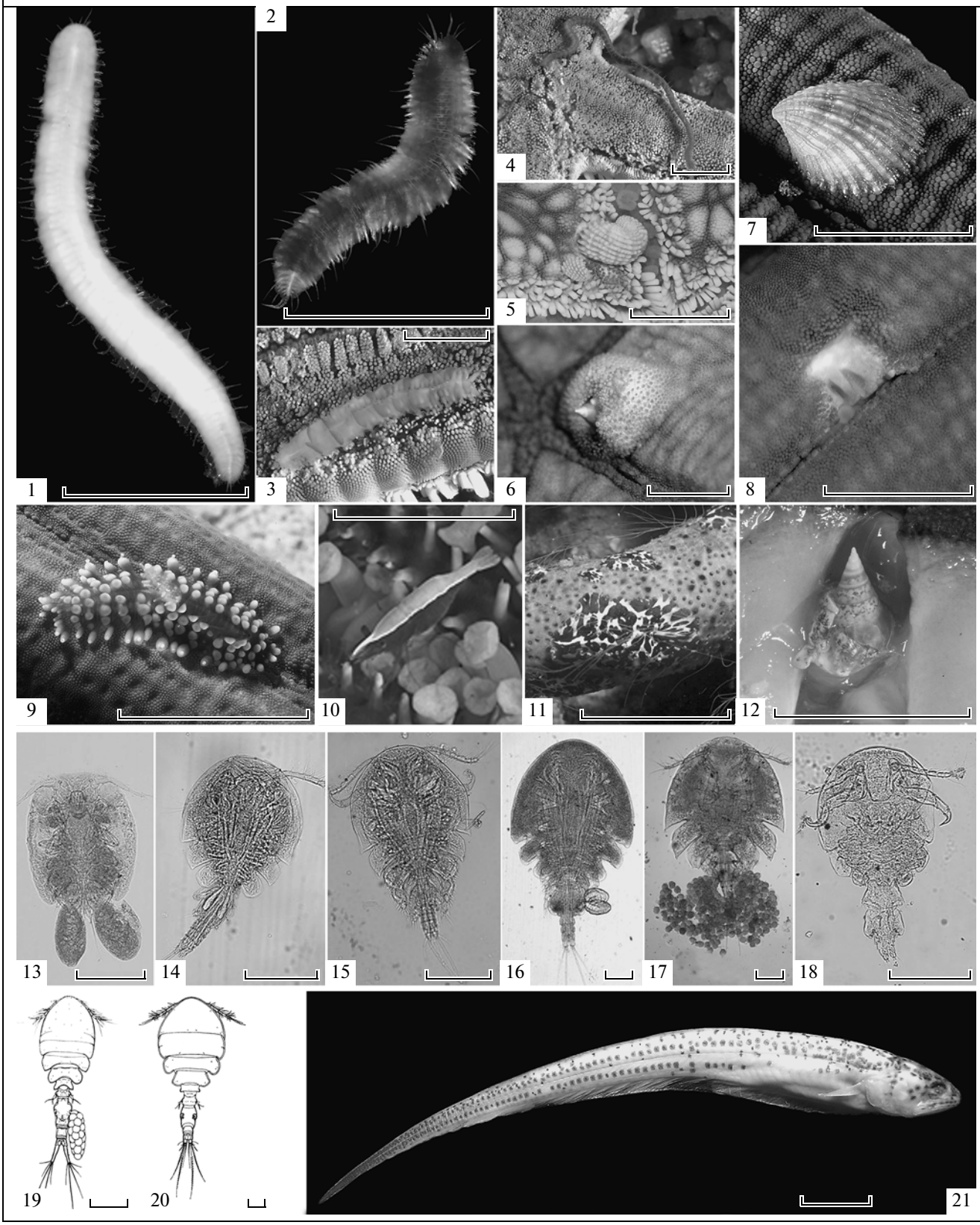
Locality in the bay: Tre Island.

Depth: 3–20 m.

Distribution: Indian Ocean, South China Sea, Japan.

Hosts: *Luidia maculata.*

Plate 8



Explanation of Plate 8

Figs. 1–20. (1) polychaete *Hololepidella millari*, (2) polychaete *Hololepidella laingensis,* (3) polychaete *Pottsiscalisetosus praelongus* on the aboral side of *Archaster angulatus*, (4) polychaete *Ophiodromus* sp. on the aboral side of *Archaster angulatus*, (5) mollusk *Granulithyca nardoafrianti* on the oral side of *Nardoa frianti*, (6) mollusk *Stilifer* sp. 2 on the oral side of *Linckia laevigata*, (7) mollusk *Thyca crystallina* on the oral side of an arm of *Linckia laevigata*, (8) traces of attachment of the mollusk *T. crystallina* on the oral side of an arm of *Linckia laevigata*, (9) polychaete *Asterophylia culcitae* on the oral side of an arm of *Linckia laevigata*, (10) shrimp *Periclimenes soror* on the oral side of disk of *Acanthaster planci*, (11) ctenophoran *Coeloplana astericola* on the aboral side of a ray of *Echinaster luzonicus*, (12) mollusk *Stilifer* sp. 1 on a section of integument of *Culcita novaeguineae*, (13) copepod *Astroxynus culcitae*, (14) copepod *Stellicola caeruleus*, (15) copepod *Stellicola oreastriphilus*, (16) copepod *Doridicola echinasteris*, (17) copepod *Stellicola illgi*, (18) copepod *Stellicola parvulipes*, (19) copepod *Synstellicola affinis*, (20) copepod *Syntellicola acanthasteris*, and (21) fish *Carapus mourlani.* Scale bars: (1, 3–9, 11, 12, 21) 10 mm, (2) 5 mm, (10) 3mm, and (13–20) 0.2 mm.

Family Hesionidae

Ophiodromus* sp.

Plate 8, fig. 4

Locality in the bay: Tre Island (Mui Nam Cape).

Depth: 15–20 m.

Hosts: *Archaster angulatus*, and *Luidia maculata.*

P h y l u m Mollusca

Family Eulimidae

Granulithyca nardoafrianti* Yamamoto et Habe, 1976

Plate 8, fig. 5

Locality in the bay: Mot, Nok, and Tre islands.

Depth: 5–20 m.

Distribution: Japan and South China Sea.

Hosts: *Nardoa frianti.*

Note: induces semicircular scars on the ventral surface of sea star hosts.

Thyca crystallina* (Gould, 1846)

Plate 8, figs. 7 and 8

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Depth: 3–20 m.

Distribution: tropical Indo-West Pacific.

Hosts: *Linckia laevigata.*

Note: induces round scars with a hole in the center and transverse grooves on the side at the attachment on the ventral surface of sea star hosts.

Stilifer* sp. 1

Plate 8, fig. 12

Locality in the bay: Tre, Mot, Mun, Nok, and Dung islands.

Depth: 3–20 m.

Hosts: *Culcita novaeguineae.*

Stilifer* sp. 2

Plate 8, fig. 6

Locality in the bay: Tre, Mot, Nok, and Dung islands.

Depth: 3–20 m.

Hosts: *Linckia laevigata.*

Note: induces swollen sites with a hole on the ventral surface of sea star hosts.

P h y l u m Arthropoda

S u b p h y l u m Crustacea

Order Decapoda

Family Palaemonidae

Periclimenes soror* Nobili, 1914

Plate 8, fig. 10

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Depth: 3–25 m.

Distribution: tropical Indo-West Pacific, including Red Sea.

Hosts: *Acanthaster planci, Choriaster granulatus, Culcita novaeguineae, Halityle regularis, Pentaceraster regulus, Protoreaster nodosus, Linckia laevigata, Nardoa frianti, Echinaster luzonicus*, and *Eureaster insignis.*

***Periclimenes imperator* Bruce, 1967**

Locality in the bay: Dung Island.

Depth: 20 m.

Distribution: tropical Indo-West Pacific, including Red Sea.

Hosts: *Eureaster insignis.*

Order Copepoda

Astroxynus culcitae* Humes 1971

Plate 8, fig. 13

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Depth: 3–20 m.

Distribution: Marshall Islands, New Caledonia, Molluccas Islands, and South China Sea.

Hosts: *Culcita novaeguineae.*

Doridicola echinasteris* (Humes, 1976)

Plate 8, fig. 16

Locality in the bay: Nok Island.

Depth: 3–20 m.

Distribution: Mauritius Island, South China Sea, New Caledonia, Molluccas Islands.

Hosts: *Echinaster luzonicus*.

Stellicola caeruleus* (Stebbing 1900)

Plate 8, fig. 14

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Depth: 3–20 m.

Distribution: South China Sea, Papua New Guinea, Molluccas Islands.

Hosts: *Linckia laevigata*.

Stellicola illgi* Humes 1973

Plate 8, fig. 17

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Depth: 3–20 m.

Distribution: South China Sea, Palau Islands, Fiji, Molluccas Islands.

Hosts: *Linckia laevigata*.

Stellicola oreastriphilus* Kossmann 1877

Plate 8, fig. 15

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Depth: 3–20 m.

Distribution: Red Sea, Madagascar, South China Sea, New Caledonia, Molluccas Islands.

Hosts: *Acanthaster planci, Choriaster granulatus, Culcita novaeguineae, Pentaceraster regulus, Linckia laevigata*, and *Echinaster luzonicus*.

Stellicola parvulipes* Humes 1976

Plate 8, fig. 18

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Depth: 3–20 m.

Distribution: South China Sea, New Caledonia, Molluccas Islands.

Hosts: *Culcita novaeguineae*.

Syntellicola acanthasteris* Humes 1970

Plate 8, fig. 20

Locality in the bay: Tre, Mot, Mun, Nok, and Dung islands.

Depth: 5–20 m.

Distribution: South China Sea, Marshall Islands, Fiji, New Caledonia.

Hosts: *Acanthaster planci*.

Synstellicola affinis* (Humes and Ho, 1967)

Plate 8, fig. 19

Locality in the bay: Tre, Mot, Mun, Nok, and Dung islands.

Depth: 5–20 m.

Distribution: Madagascar and South China Sea.

Hosts: *Linckia laevigata*.

Phylum Chordata

SUPERCLASS PISCES

Family Carapidae

***Carapus mourlani* (Petit, 1934)**

Plate 8, fig. 21

Locality in the bay: Tre, Mieu, Tam, Mot, Mun, Nok, and Dung islands.

Depth: 3–25 m.

Distribution: Madagascar, Mozambique, Seychelles, South Africa, South China Sea, and Chagos.

Hosts: *Archaster angulatus, Culcita novaeguineae*, and *Linckia laevigata*.

DISCUSSION

Our studies considerably expanded the data on the sea star fauna of Vietnam. In the Bay of Nhatrang, we recorded 39 sea star species of 13 families; 19 of them are new for this region. More than half of species (61.6%) belong to the families Oreasteridae and Ophidiasteridae. All species are typical members of the Indo-West Pacific fauna. Of 39 sea star species, 15 were previously recorded at the coast of Khanh Hoa Province (Vietnam), where the Bay of Nhatrang is located (Ho, 2002), while eight species, *Astropecten monacanthus* Sladen 1883, *Archaster typicus* Müller and Troschel 1840, *Pentagonaster japonicus* Sladen 1889 (invalid species), *Fromia hadracantha, Leiaster brevispinus, Linckia guildingi, Asterina belcheri*, and *Asteropsis carinifera*, have not been recorded by us in the Bay of Nhatrang. Thus, to date, a total of 47 sea star species have been recorded in the coastal waters of Vietnam. In one of the most complete reports on the echinoderm fauna of the South China Sea (Lane et al., 2000), 237 sea star species are listed. Against this background, the Vietnamese fauna looks rather poor. However, note that about 100 sea star species mentioned in this report dwell at more than 50 m of depth. At the same time, the sea star diversity of the Bay of Nhatrang is high compared to shallow-water faunas of other regions. In particular, Taiping Island (South China Sea, Spratly Archipelago) has yielded only eight sea star species (Jeng, 1998); Anambas and Natuna islands (South China Sea, Indonesia) have 28 species (Purwati, 2002); Thailand (South China Sea and Andaman Sea) has 69 species (Putchakarn, 2004); Taiwan (South China Sea) has 31 species (Chao, 1999); Guam has 24 species (Yamaguchi, 1975); and southeastern Polynesia has 25 species (Marsh, 1974). The taxonomic composition of sea star faunas of particular regions of the South China Sea (Vietnam,

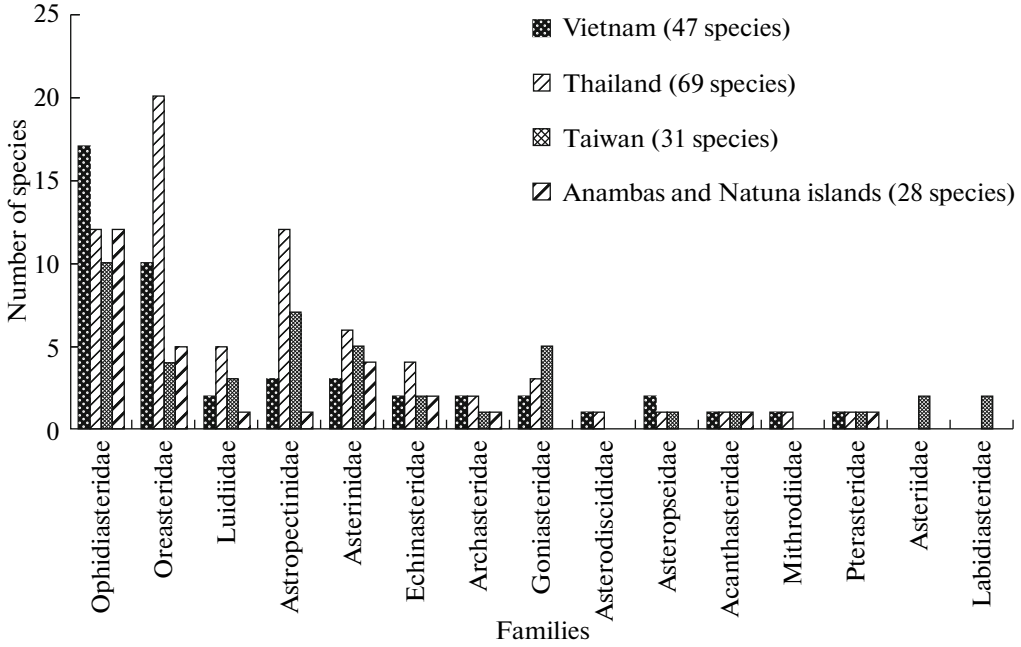


Fig. 2. Taxonomic composition of the sea star fauna in different regions of the South China Sea.

Thailand, Taiwan, and Anambas and Natuna islands in the southern South China Sea) is similar (Fig. 2). In all cases, the same families Ophidiasteridae and Oreasteridae are represented by the greatest number of species. The differences in the species composition of other families (such as Astropectenidae, Luidiidae, Asteriidae, and Labidiasteridae) are connected primarily with the fact that deepwater and soft ground sea star faunas of these regions have been investigated to different extent.

The fauna of symbionts associated with tropical sea stars of the Bay of Nhatrang includes more than 25 species of various taxa. Eighteen symbiotic species are recorded in Vietnam for the first time. The fauna of obligatory macrosymbionts of sea stars of the Bay of Nhatrang includes 21 species (one sedentary ctenophoran, five polychaetes, four mollusks, two shrimps, eight copepods, and one fish).

Symbionts were found in 13 sea star species (33.3% of the total number of species). The absence of symbionts in remaining 29 species is probably connected with nonuniform distribution of symbionts over hosts and small sample sizes of these sea stars rather than with features of their morphology, habitats, or taxonomic affinity.

All symbionts examined inhabit only echinoderms, occupying a rather wide range of hosts (Table 1). With reference to host specificity, the symbionts are divided into two groups: specialized obligatory symbionts of sea stars (*Periclimenes soror, Hololepidella millari, Stilifer* sp. 1, *Stilifer* sp. 2, *Thyca crystallina, Granulithyca nardoafrianti, Syntellicola acanthasteris, Stellicola caeruleus, S. illgi, S. oreastriphilus, Stellicola parvulipes, Synstellicola affinis, Doridicola echinasteris*, and *Astroxynus culcitae*) and species inhabiting not only sea stars but also other echinoderm groups, holothuroids and crinoids (*Carapus mourlani, Hololepidella laingensis*, and *Asterophilia culcitae*). For the species *Periclimenes soror, Asterophylia culcitae, Hololepidella laingensis, Hololepidella millari*, and *Carapus mourlani* the list of sea star hosts is expanded.

The data on the fauna of sea star symbionts of tropical seas are provided by isolated publications with descriptions of particular symbionts (e.g., Pettibone, 1969; Bruce, 1982; Waren, 1983). At the same time, the fauna of sea star symbionts of the northeastern Atlantic is relatively thoroughly investigated (Barel and Kramers, 1977). Therefore, we only included in comparison macrosymbionts listed in this study and excluded species that accidentally occurred on sea stars (Fig. 3). As was expected, considerable differences are observed even at the level of high-rank taxa (Fig. 3). In particular, symbiotic ctenophorans, mollusks, decapods, or fishes have not been recorded in the northeastern Atlantic. Our samples lack ascothoracid crustaceans; however, this is connected with the methods used rather than actual absence of these symbionts.

Abundant Atlantic amphipods are mostly represented by facultative symbionts, whereas our work

Table 1. Hosts of macrosymbiotic species of sea stars (excluding copepods)

Sea star species	Symbiont species																	
	Carapus mourlani		*Periclimenes soror*		*Hololepidella laingensis*		*Hololepidella millari*		*Asterophilia culcitae*		*Stilifer* sp. 1		*Stilifer* sp. 2		*Thyca crystallina*		*Granulithyca nardoafrianti*	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Asteroidea																		
Acanthaster planci		+	+	+	+		+											
Acanihaster brevispina				+														
Archaster angulatus	+																	
Choriaster granulatus		+	+	+			+		+	+								
Culcita novaegaineae	+	+	+	+	+		+		+		+							
Citicita schmideliana		+		+														
Eareaster insignis			+				+		+									
Echinaster lusonicus			+						+									
Echmaster purpureus				+														
Halityle regularis			+				+											
Linckia guildingui								+										
Linckia laevigata	+		+		+		+	+	+	+			+		+	+		
Linckia multifora				+														
Nardoa frianti			+														+	+
Mithrodia clavigera				+														
Mithrodia bradleyi				+														
Pentaceraster hawaiiensis				+														
Pentaceraster horridus				+														
Pentaceraster mammillatus				+														
Pentaceraster tuberculatus				+														
Pentaceraster regulus			+	+														
Pentaceroa hawaiiensis		+																
Protoreaster lincki		+		+														
Protoreaster nodosus			+	+			+			+								
Thromidia seycheilensis		+																
Holothuroidea																		
Actinopyga muritiana		+																
Bohadschia argits		+																
Holotharia scabra		+																
Stichopus chloronotus		+																
Stichopits variegatus		+																
Crinoidea																		
Capillaster multiradiatus						+												
Dichometra flagellate						+												
Himerometra robastipinna						+												
L amprometra palmate						+												
Oxycomanthus bennetti						+												
Unidentified sp.										+								

Note: (a) based on the study of sea star symbionts in the Bay of Nhatrang and (b) based on published data.

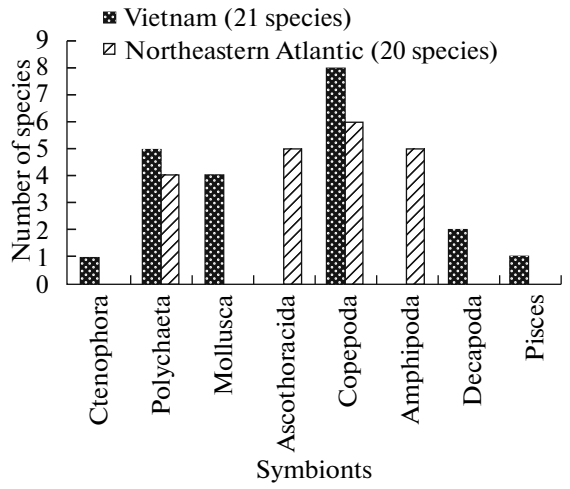


Fig. 3. Taxonomic composition of the fauna associated with sea stars of Vietnam and the northeastern Atlantic.

involves only obligatory symbionts. Only two genera, *Ophiodromus* (Polychaeta) and *Stellicola* (Copepoda), are shared by symbiont faunas of the two regions; however, none of species are shared because of essential differences between the faunas of the Atlantic and Indo-West Pacific. Taking into account the fact that our data concern the water area of one small bay and 13 sea star species, whereas the review of Barel and Kramers (1977) involves the water area of the entire northeastern Atlantic and 38 sea star species, the diversity of Vietnam should be regarded as rather high.

In a faunal study, it is difficult to estimate the character of symbiont–host relationships. At the same time, four symbiotic species considered injure soft tissues and skeleton of hosts. These are mollusks of the family Eulimidae: *Granulithyca nardoafrianti, Thyca crystallina*, and *Stilifer* sp. 2. These species produce scars on the ventral surface of sea star hosts and the shape of scars depends on the mollusk species (Pl. 6, figs. 6, 8). It is interesting that similar scars were recorded in fossil species of the sea urchin genus *Oichnus* (Neumann and Wisshak, 2009). This promises an opportunity to identify symbionts based on the shape of injuries in fossil echinoderms.

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REFERENCES

Barel, C.D.N. and Kramers, P.G.N., A Survey of the Echinoderm Associates of the North-East Atlantic Sea, *Zool. Verhandelingen*, 1977, vol. 156, pp. 1–159.

Britayev, T.A., Smurov, A.V., Adrianov, A.V., Bazhin, A.G., and Rzhavsky, A.V., Ecology of Symbionts of the Polychaete *Arctonoe vittata* in Connection with Biological Features of the Host Sea star *Asterias ratbunae*, in *Simbioz u morskikh zhivotnykh* (Symbiosis in Marine Animals), Sveshnikov, V.A., Ed., Moscow: Inst. Evol. Morfol. Ekol. Zhivotn. Akad Nauk SSSR, 1989, pp. 102–127.

Britayev, T.A. and Fauchald, K., New Species of Symbiotic Scaleworms Asterophilia (Polychaeta, Polynoidae) from Vietnam, *Invertebr. Zool.*, 2005, vol. 2, no. 1, pp. 15–22.

Bruce, A.J., The Shrimps Associated with Indo-West Pacific Echinoderms, with the Description of a New Species in the Genus *Periclimenes* Costa, 1844 (Crustacea: Pontoniinae), *Austral. Mus. Mem.*, 1982, vol. 16, pp. 191–216.

Chao, S., Revision of Taiwan Sea star (Echinodermata: Asteroidea), with Description of Ten New Records, *Zool. Stud.,* 1999, vol. 38, no. 4, pp. 405–415.

Clark, A.M. and Rowe, F.W.E., Monograph of Shallow-Water Indo-West Pacific Echinoderms, London: Trust. Brit. Mus. Natur. Hist., 1971, p. 238.

Dawydoff, C., Contribution a l'etude des invertebres de la faune marine benthique de l'Indochine, *Contrib. Inst. Oceanogr. Nhatrang*, 1952, vol. 9, p. 228.

Fjukmoen, Ø., The Shallow-Water Macro Echinoderm Fauna of Nha Trang Bay (Vietnam): Status at the Onset of Protection of Habitats, *Master Thes. Marine Biol. Degree*, Bergen: Univ. Bergen, Inst. Biol., 2006.

Hartmann-Schroder, G., *Hololepidella alba* n. sp. (Polynoidae: Polychaeta), a Commensal with the Crown-of-Thorns Sea star from Mactan, Cebu, *Philippine Sci.*, 1981, vol. 18, pp. 10–14.

Ho D.T., *Check List of Echinoderms in Vietnam*, vol. 1: *Crinoidea and Echinoidea*, Hanoi: Sci. Tech. Publ. House, 1994.

Ho D.T., *Statistics of a Sample of Echinoderms at the Institute of Oceanography Museum*, 2001.

Ho D.T.., The Echinoderm Fauna in the Coastal Waters of Khanh Hoa Province (Central Vietnam), *J. Mar. Sci. Tech.*, 2002, vol. 1, pp. 1–11.

Humes, A.G., Cyclopoid Copepods Associated with Asteroid Echinoderms in New Caledonia, *Smithsonian Contrib. Zool.,* 1976, vol. 217, pp. 1–19.

Jangoux, M., Diseases of Echinodermata, in *Diseases of Marine Animals*, Kinne, O., Ed., Hamburg: Biol. Anstalt Helgoland, 1990, vol. 3, pp. 439–567.

Jeng, M.-S., Shallow-Water Echinoderms of Taiping Island in the South China Sea, *Zool. Stud.*, 1998, vol. 37, no. 2, pp. 137–153.

Lane, D.J.W., Marsh, L.M., Vandenshpiegel, D., and Rowe, F.W.E., Echinoderm Fauna of the South China Sea: An Inventory and Analysis of Distribution Patterns, *Raffles Bull. Zool.*, 2000, no. 8, pp. 459–493.

Marsh, L.M., Shallow-Water Asterozoans of Southern Polynesia: 1. Asteroidea, *Microneses. J. Coll. Guam*, 1974, vol. 10, pp. 65–104.

Ming-Shiou, J., Shallow-Water Echinoderms of Taiping Island in the South China Sea, *Zool. Stud.*, 1998, vol. 37, no. 2, pp. 137–153.

Neumann, C. and Wisshak, M., Gastropod Parasitism on Late Cretaceous to Early Paleocene Holasteroid Echinoids—Evidence from *Oichnus halo* sp. n, *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 2009, vol. 284, pp. 115–119.

Pettibone, M.H., Remarks on the North Pacific *Harmothoe tenebricosa* Moore (Polychaeta, Polynoidae) and Its Association with Asteroids (Echinodermata, Asteroidea), *Proc. Biol. Soc. Washington*, 1969, vol. 82, pp. 31–42.

Purwati, P. and Lane, D.J.W., Asteroidea of the Anambas Expedition 2002, *Raffles Bull. Zool.,* 2004, vol. 11, pp. 89–102.

Putchakarn, S. and Sonchaeng, P., Echinoderm Fauna of Thailand: History and Inventory Reviews, *Science Asia*, 2004, vol. 30, pp. 417–428.

Waren, A., A Generic Revision of the Family Eulimidae (Gastropoda, Prosobranchia), *J. Mollusc. Stud.*, 1983, vol. 13, pp. 1–96.

Yamaguchi, M., Coral Reef Asteroids of Guam, *Biotropica*, 1975, vol. 7, pp. 12–23.