1-3 Distribution of coral reef communities

Makoto Tsuchiya
Illustrations by Moritaka Nishihira

Introduction

Coastal ecosystems often occurring in association with coral reefs include rocky coasts, sandy beaches, tidal flats and seagrass meadows. Mangrove forests are also frequently found around river mouths. In this chapter, coral reef communities and their distribution are diagrammatically illustrated, and their geographical and ecological distribution patterns are outlined.

In Japan, coral reefs are relatively widely distributed over latitudes spanning more than 1,000 km; these reefs exhibit a range of reef communities. In the past, comprehensive surveys of coral reef communities have been conducted at several reefs, for example in the Senkaku Islands, Sesoko Island and Kabira Bay. There is a shortage of up-to-date quantitative research on community structure, although qualitative descriptions of the distributions of certain reef organisms, such as mollusks and crustaceans, have been published in many illustrated encyclopedias in Japan.

Habitats such as sandy beaches, rocky coasts with characteristic notch morphology, reef flats, backreef lagoons, reef edges, and reef slopes harbor different characteristic communities. In the backreef lagoon for example, there are places covered with rocky carbonate or with sandy particles. Common species observed in this habitat include the seagrasses *Thalassia hemprichii* and *Cymodocea serrulata*, the sea urchins *Echinometra mathaei*, *Tripneustes gratilla* and *Diadema setosum*, and the sea cucumbers *Holothuria leucospilota*, *H. atra*, *Synapta maculata* and *Bohadschia argus*. Corals are also frequently patchily distributed. However the densities of acroporid and pocilloporid corals have decreased in recent years, owing to disturbances such as the discharge of terrigeneous fine particles (e.g., red soil), high predation pressure by the crown-of-thorns starfish (*Acanthaster planci*), and bleaching events. Reports on the distribution of these species are freely available (JCRS 2002).

Cadret *et al.* (1999) studied the distribution of butterflyfish communities at 45 stations on the reefs of five islands within an area of 500 × 300 km (24–27°N; 124–128°E). A total of 30 species were recorded, and the overall species composition of communities from the various reefs was rather similar; it did differ, however, in a number of different habitats, such as the reef slope and backreef lagoon. It has been suggested that habitat heterogeneity and the abundance of coral species may affect community structure. Tsuchiya and Fai (in press) reported that the number of species of the xanthid crab *Trapezia*, which are obligate symbionts on pocilloporoid corals, did not differ significantly across several sites of similar area. However, the number of species was lower in Kumamoto (33°N; 130°E), ca. 800 km north of Okinawa, where the host coral *Pocillopora damicornis* is very abundant. The brooders *P. damicornis* and *Stylophora pistillata*, which are widely distributed in the Ryukyu Islands, showed genetic differences in different localities (Adjeroud and Tsuchiya 1999; Nishikawa *et al.* 2003), while the spawner *Acropora tenuis* did not show any such differences (Nishikawa *et al.* 2003).

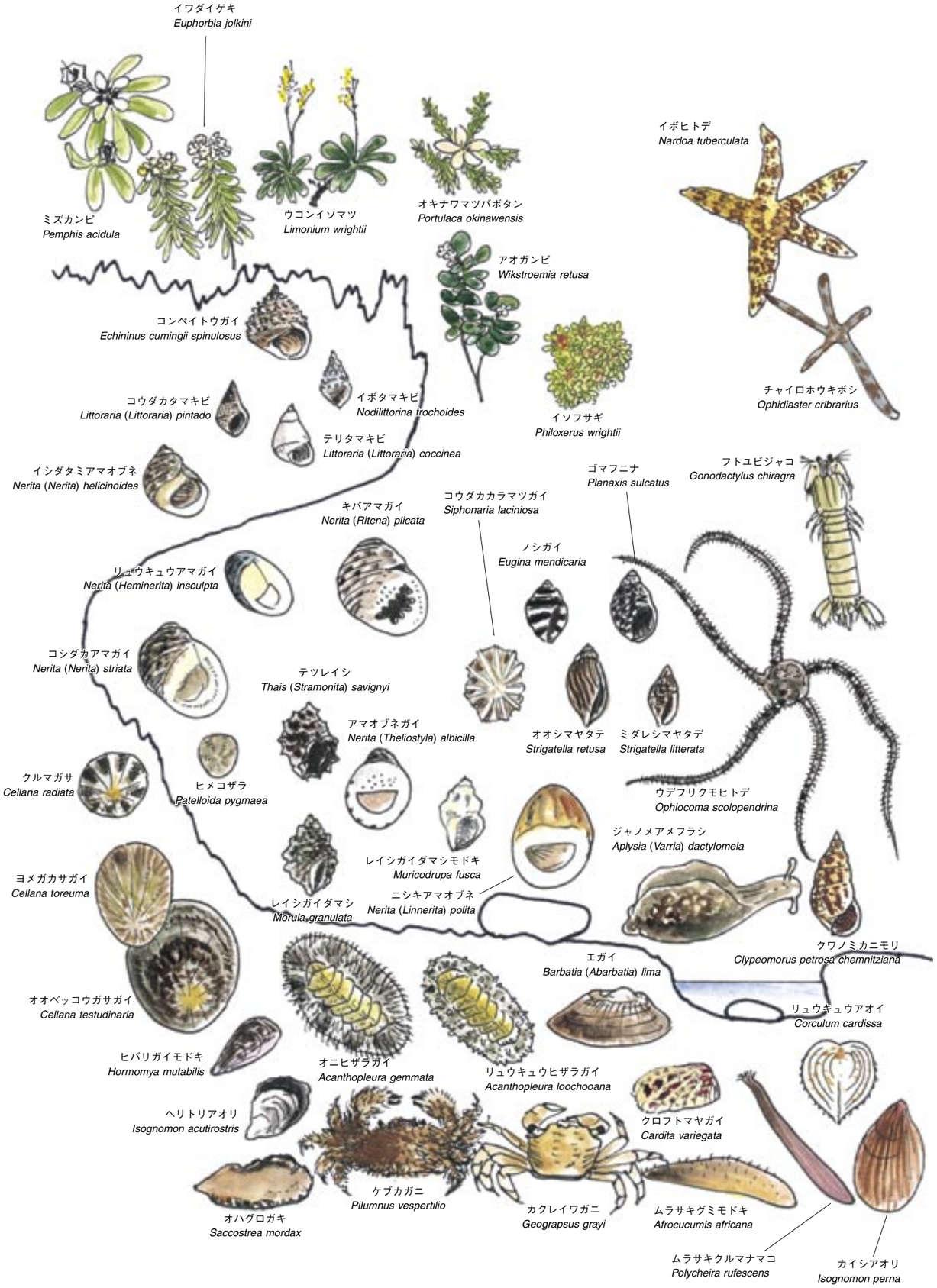
The zonation, growth, and habitat use of the calcareous algae of the Okinawan coral reefs has been the subject of ecological and reproductive research (Matsuda 2002). Ten species of seagrass were reported in the Ryukyu Islands (Yokochi 2002), with only three species occurring in the northern part of the archipelago, e.g., in the coastal area of Tanegashima Island. Their distribution and reproductive traits have also been well-researched. A list containing seaweeds of 548 species in 209 genera has been produced by Tsuda (1991), but the analyses of their overall distribution patterns are inadequate.

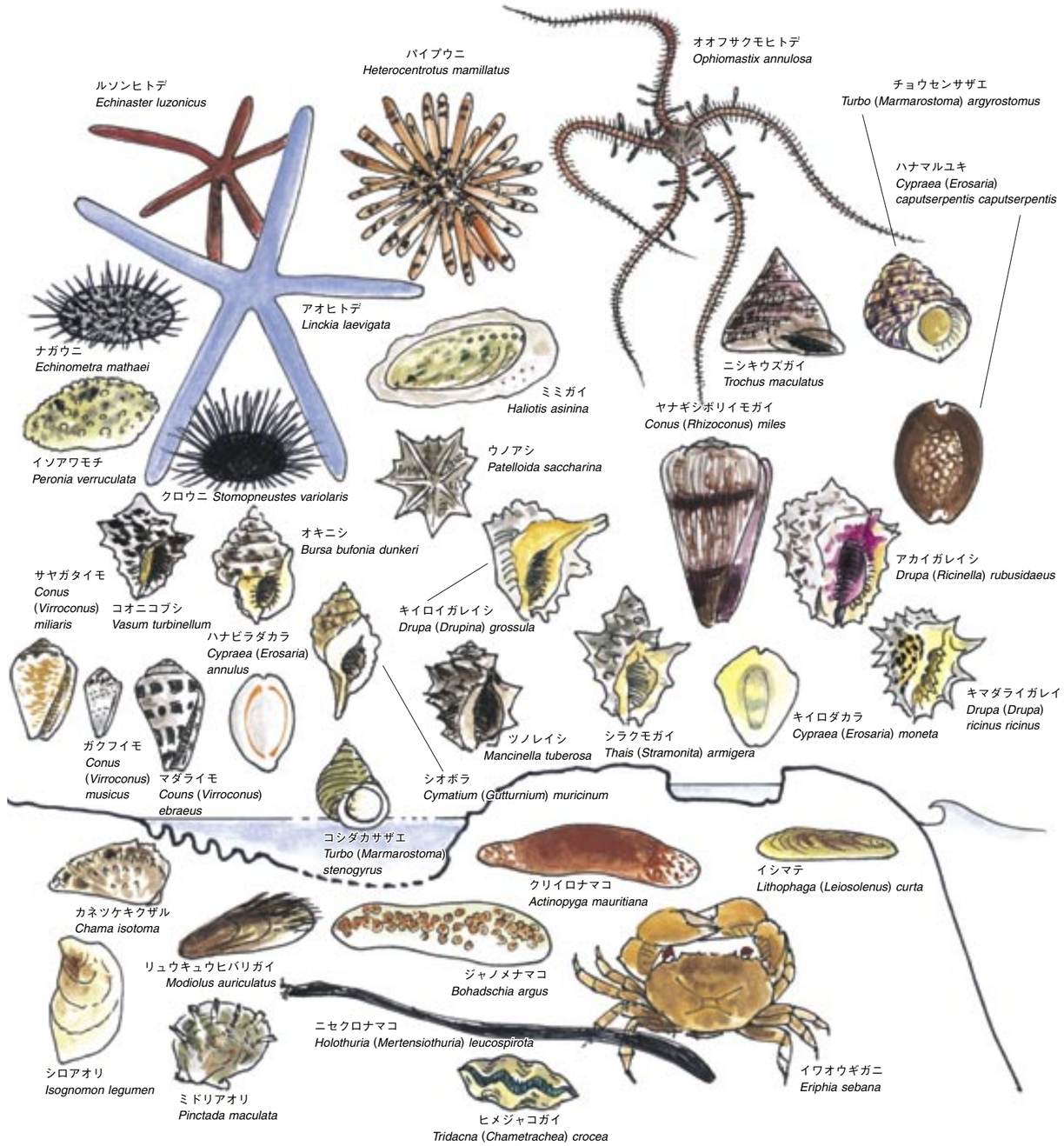
Biodiversity and ecosystem issues are currently widely discussed topics. Coral reefs, with their wide variety of biotic and abiotic interactions, constitute appropriate examples for the discussion of mechanisms that promote the coexistence of diverse species. Information on the geographical and ecological distribution of various species is essential for these analyses.

Communities in rocky intertidal zones. Part I

The vertical tidal range in Okinawa is about 2 m during spring tides and 25 cm at neap tides. Diverse species inhabit this heterogeneous environment.

As the rocky intertidal zone is quite flat in coral reef areas, there is no conspicuous zonation of organisms. However, distinct distribution patterns of intertidal organisms can be observed by walking across the reef from the land towards the reef edge. A variety of intertidal animals and plants can be seen, including, mobile species, sessile species, fishes in tidal pools, animals associated with other organisms, and seaweeds, showing seasonal variation. The mechanisms by which they have adapted to the diverse intertidal environment, their feeding habits, species interactions and so on, help us to understand why coral reef organisms are so diverse.





Communities in rocky intertidal zones. Part II

1. Littoral fringe

This zone is categorized as the area located between the upper limit of littorinid gastropod distribution and the area of barnacle distribution, the latter being the upper limit of the eulittoral zone (Lewis 1964). In the Ryukyu Islands, this zone is also the habitat for terrestrial plants such as *Limonium wrightii* and *Piloxerus wrightii*, which coexist with the littorinid *Echininus cumingii spinulosis*. This species usually inhabits the inside of rock crevices, but leaves this shelter during sunny days in the summer. Individuals often overlap to form double or triple layers, a behavior which seems to be designed to prevent over-heating on the rock surfaces (Photo. 1). This behavior is more conspicuous in another littorinid species *Nodilittorina pyramidalis*, which is abundant in the upper part of the eulittoral zone (Photo. 1-2). The gastropod, *Ritena plicata*, is commonly seen in the lower part of the littoral fringe. Vertical migrations of *R. plicata* are often associated with environmental changes; for example, their distribution zone is sometimes 1–2 m higher than normal just after a typhoon passes.

2. Eulittoral zone

The upper limit of the barnacle zone in coral reef areas is not as conspicuous as it is in temperate zones, due to the scarcity of barnacles. The lower limit of the eulittoral zone in the temperate intertidal zone is defined as the upper limit of the habitat of macroalgae such as *Laminaria* and *Undaria*, but in coral reef areas it should instead be defined by the upper limit of the habitat of coral species (Nishihira 1974).

The eulittoral zone of coral reef areas in Okinawa consists mostly of reef flat. The gastropod *Planaxis sulcatus* (Photo. 2-1), the small bivalve *Isognomon* (*Parviperna*) *acutirostris*, and the oyster *Saccostrea mordax* (Photo. 2-2), are abundant on the landward side, where they frequently aggregate densely. During the cold season (January to March), the green algae *Ulva, Monostroma* and *Enteromorpha* cover the rock surface, and provide large quantities of nutrients to coral reef organisms as they decompose in the summer months. *Monostroma nitidum* is one of the most important food items in Okinawa, and is commonly harvested during the spring season. Small hermit crabs aggregate on rocks during high tides, chitons such as *Acanthopleula loochooana* and *A. gemmata* are found in rock crevices, and several species of carnivorous gastropod characterize the middle part of the eulittoral zone. The dominant species in the lower eulittoral zone is the sea urchin *E. mathaei*. Okinawan specimens have been well studied; recently, they were divided into four types, according to their morphological, ecological and developmental characteristics (Arakaki and

Photo. 1. Littorinids that inhabit rocky shores often overlap with other individuals to form double or triple layers, a behavior that seems to be designed to prevent over-heating on the rock surfaces.
(1) *Echininus cumingii spinulosis*
(2) *Nodilittorina pyramidalis*

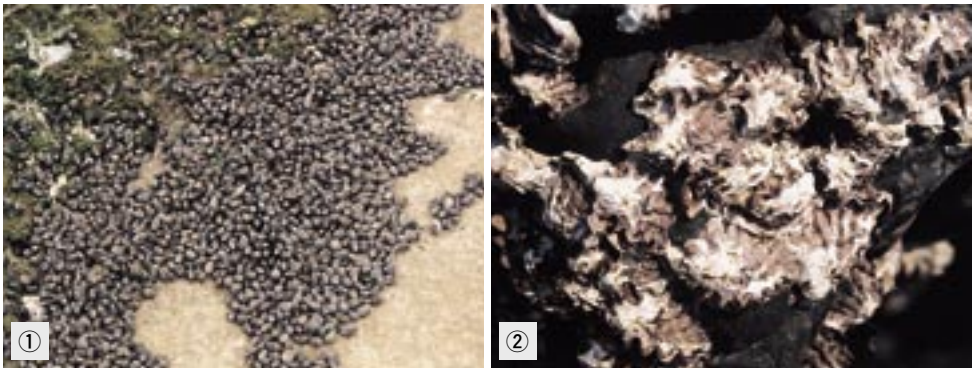


Photo. 2. Some gastropods (1) and oysters (2) frequently form dense aggregations on shore-side ledges in the eulittoral zone in Okinawa.
(1) *Planaxis sulcatus*
(2) *Saccostrea mordax*

Uehara 1991; Nishihira *et al*. 1991; Uehara *et al*. 1991). Of particular interest to researchers is the agonistic behavior of the urchins, which inhibit excavated burrows on the rock surface (Tsuchiya *et al*. 1991) (Photo. 3).

A variety of species are observed in tide pools, including the sea cucumber *Bohadshia argus* (Photo. 4-1) and *Holothuria leucospilota*, the brittle star *Ophiocoma scolopendrina* (Photo. 4-2), the urchin *E. mathaei*, and some species of coral. *Pavona frondifera*, a common species in backreef lagoons and tide pools, was affected by bleaching events in 1998 and 2001, after which some subsequently recovered. *Acropora* spp. were more seriously adversely affected, showing much higher mortality at certain sites.

Acetabularia ryukyuensis (Photo. 5), which is known as a living fossil among seaweed species, has recently declined in Okinawa. Large populations of *A. ryukyuensis* are found only in areas where anthropogenic impacts have been minimal. This species usually grows on boulders or coral rubble, and since these habitats are unstable, habitat disturbance may be too high for it to persist in areas that are frequently visited by humans.

Species richness is high in the tide pools near the reef edge. The fish and coral communities are also diverse, and lobsters are occasionally observed.

3. The lower intertidal or subtidal fringe

In coral reefs, this zone corresponds to the upper part of the reef slope, the lower part of the reef edge, and the backreef on the lagoon side. The decline of coral communities is also evident in this area. Fortunately, newly recruited colonies of *Acropora* are now appearing in some places, giving hope for future recovery.

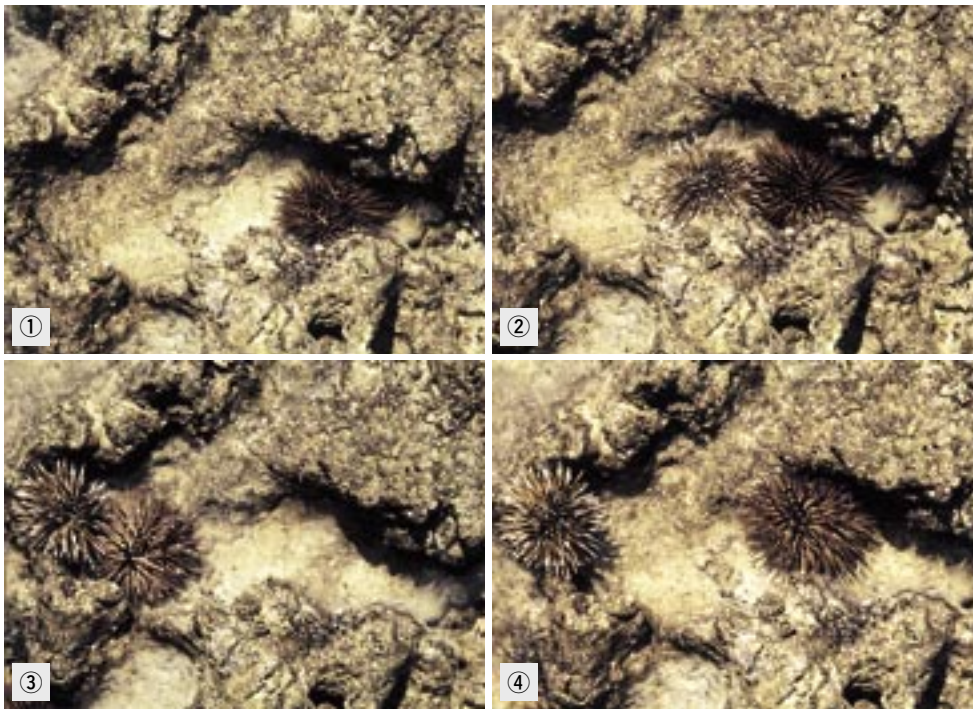


Photo. 3. Agonistic behavior of the sea urchin *Echinometra mathaei*, which inhabits excavated burrows on reef flat rocks in the eulittoral zone in Okinawa.
(1) Burrows occupied by E. mathaei type B.
(2) *E. mathaei* type A being introduced to type B's burrow.
(3) Type B driving type A out of the burrow.
(4) Type B subsequently returned to the original burrow. The behavior observed in (1)-(4) took a total of about six minutes.

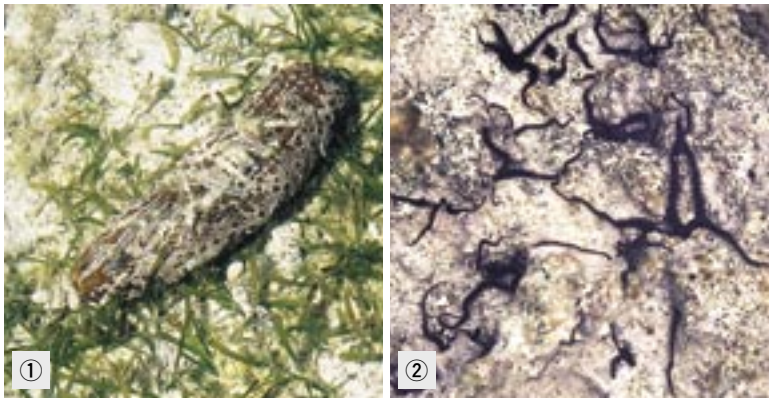
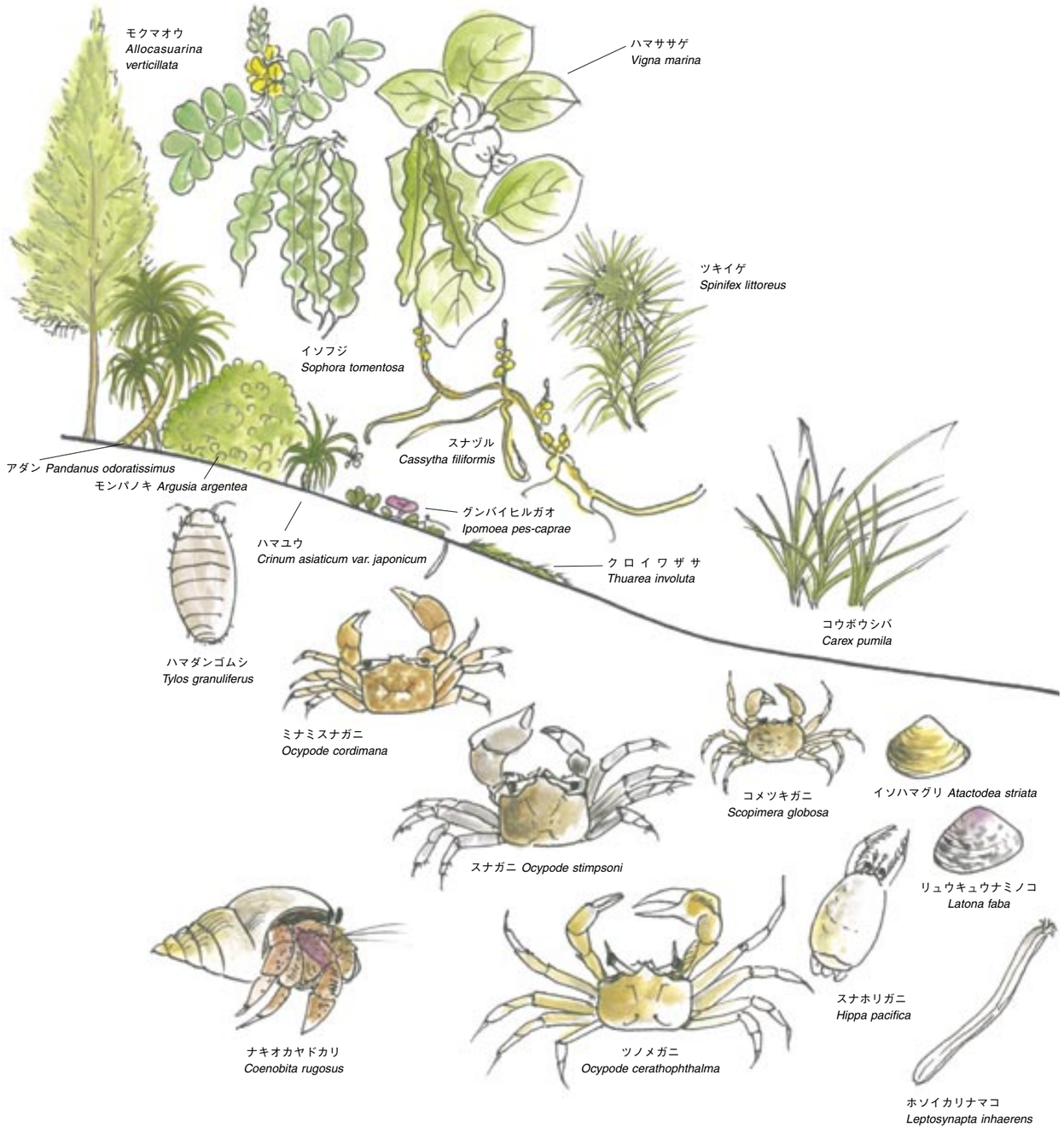


Photo. 4. Echinoderms observed in tide pools on Okinawan reefs:
(1) sea cucumber *Bohadschia argus*
(2) brittle star *Ophiocoma scolopendrina*

Photo. 5. *Acetabularia ryukyuensis* growing on boulders and coral rubble along the shore.

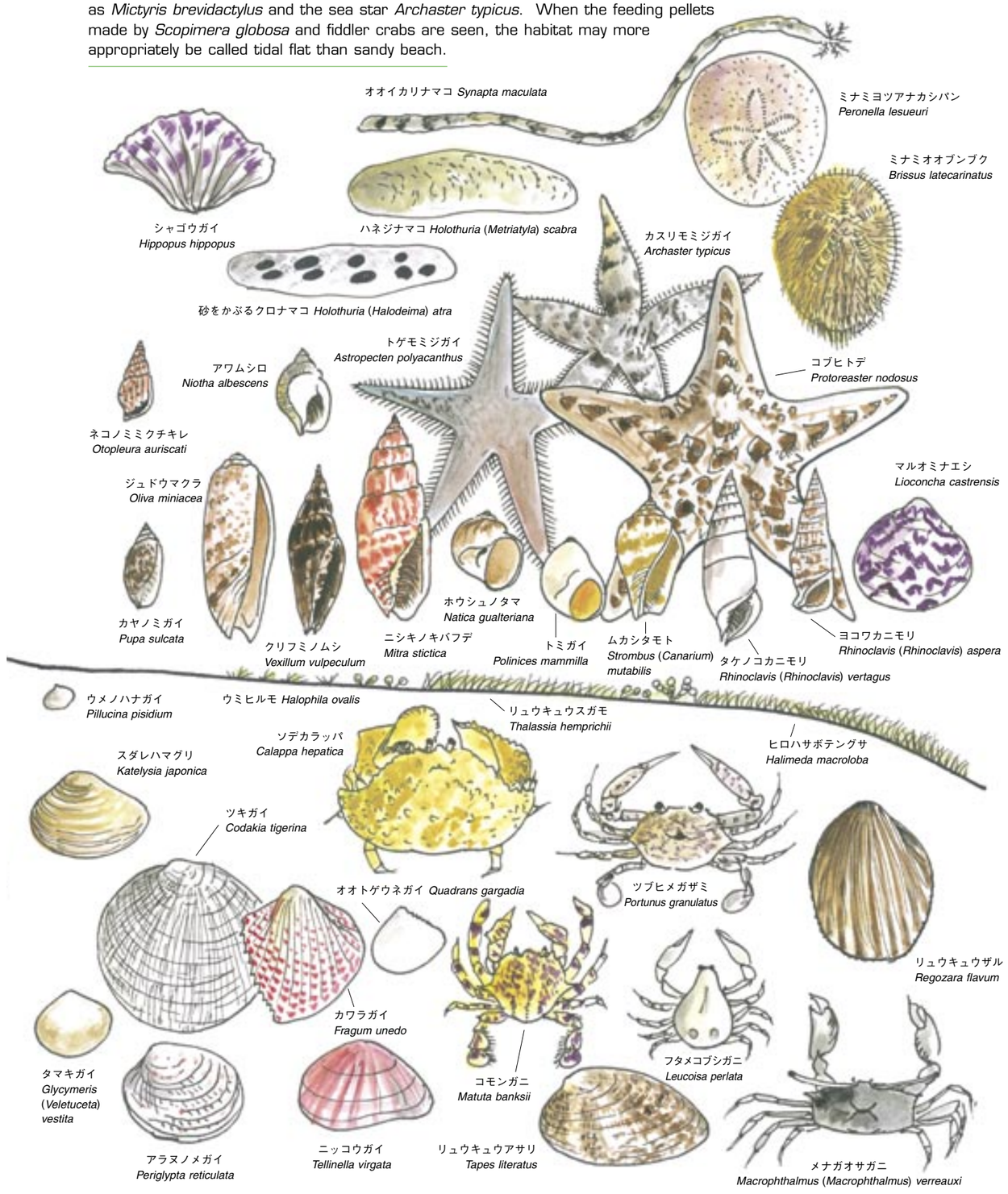
Communities on sandy beaches

Well developed sandy beaches are located along the coast on the landward side of the coral reefs. *Casuarina equisetifolia* functions as maritime forest along the back of the beaches and *Pandanus odoratissimus* and *Argusia argentea* also grow here. Herbaceous plants of the coastal plant community include *Crinum asiaticum*, *Ipomea pes-caprae* subsp. *brasiliensis*, and *Cassytha filiformis*, among which land hermit crabs *Coenobita* spp. are found. Land hermit crabs are essentially nocturnal; however, small individuals can be seen throughout the day, feeding on litter that has been left on the beach.



Typical sandy beach communities are also characterized by the rapidly moving ghost crab *Ocypode stimpsoni*, and the migrations of the hippod *Hippa pacifica* and the Pacific bean donax, *Donax* (*Latona*) *faba*.

The lower part of sandy beaches often functions as a tidal flat. Seagrasses are also often seen around the shallow subtidal zone. Sandy beaches in Okinawa usually contain elements of both sandy and tidal flat communities. Thus the flora and fauna include some species that are usually found on tidal flats but not typically on sandy beaches, such as *Mictyris brevidactylus* and the sea star *Archaster typicus*. When the feeding pellets made by *Scopimera globosa* and fiddler crabs are seen, the habitat may more appropriately be called tidal flat than sandy beach.

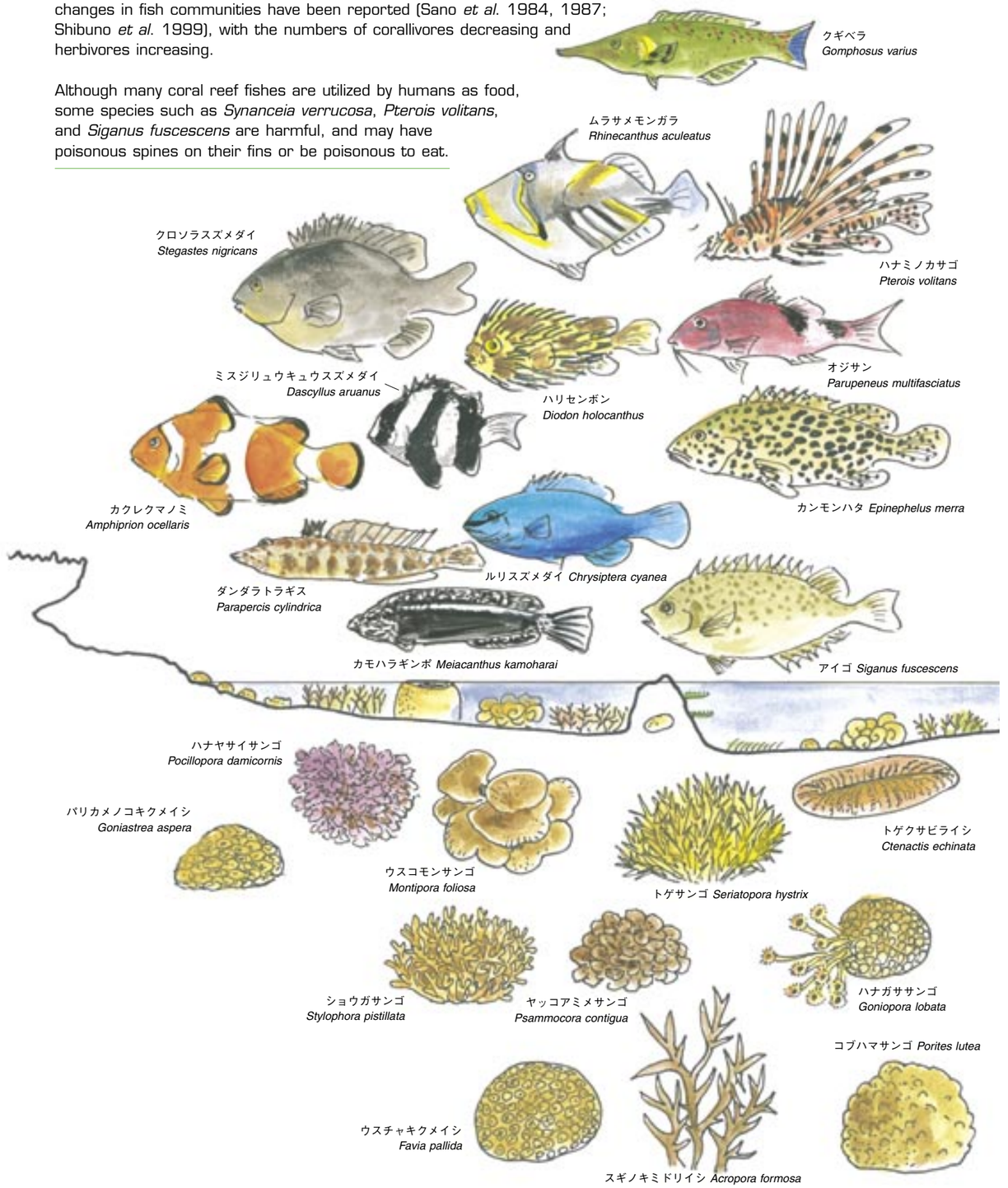


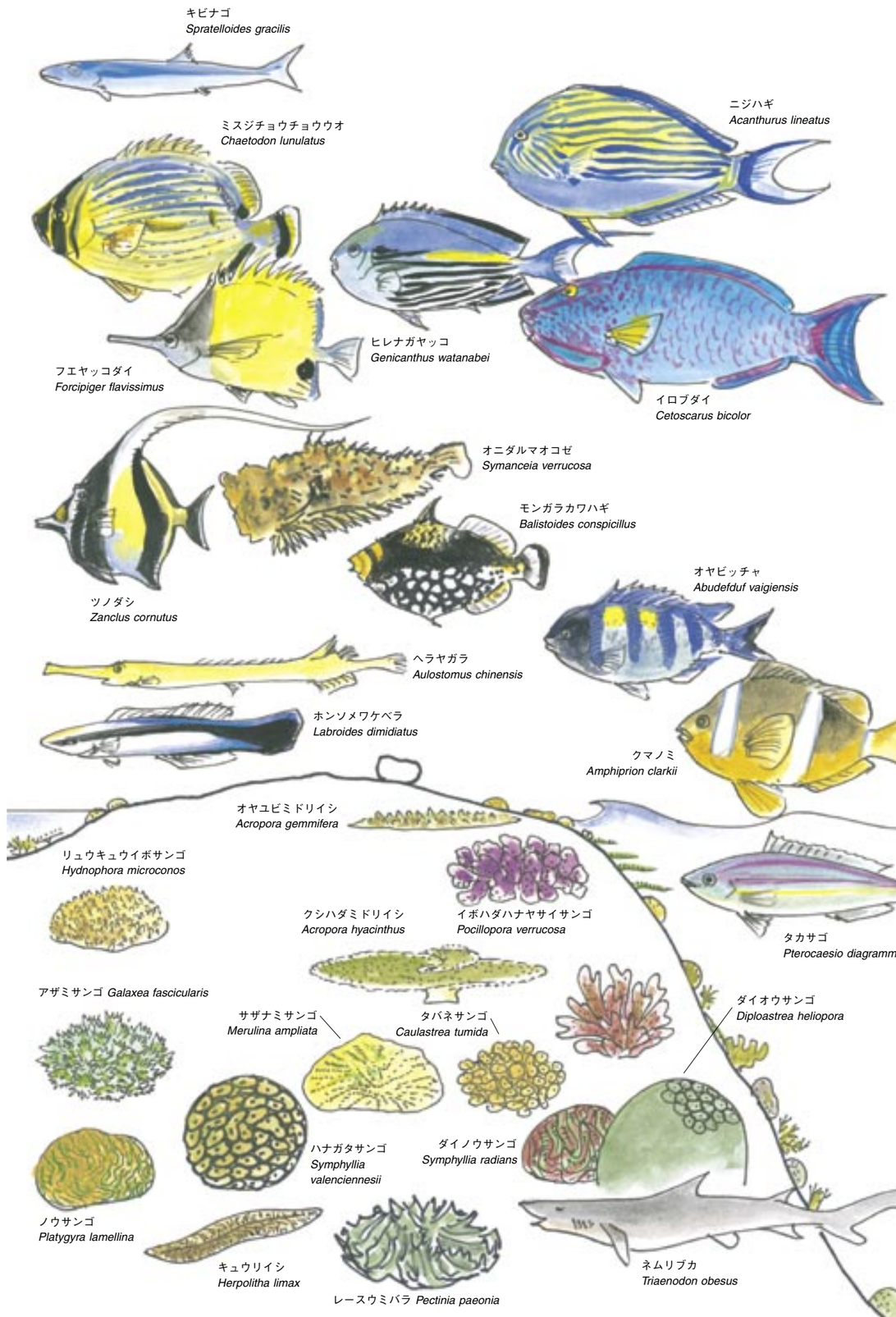
Coral reef organisms. Part I

The most typical of the organisms characterizing coral reefs are hermatypic corals. Different coral communities are observed among different habitats such as calm backreef moat, reef slopes, and high wave energy reef edges. Bleaching events have frequently occurred on many reefs and in many coral habitats; the recovery process has been observed to differ greatly among these different environments.

The life-history strategies of coral reef organisms are very diverse. They include: 1) small fishes and benthic animals using coral as shelters, 2) animals feeding on the coral, 3) animals that have symbiotic relationships with coral, and 4) other strategies. Since many reef organisms rely on coral either directly or indirectly, the physical condition of the coral is very important to the well being of many organisms. After outbreaks of *A. planci* or severe bleaching events, drastic changes in fish communities have been reported (Sano *et al*. 1984, 1987; Shibuno *et al*. 1999), with the numbers of corallivores decreasing and herbivores increasing.

Although many coral reef fishes are utilized by humans as food, some species such as *Synanceia verrucosa*, *Pterois volitans*, and *Siganus fuscescens* are harmful, and may have poisonous spines on their fins or be poisonous to eat.





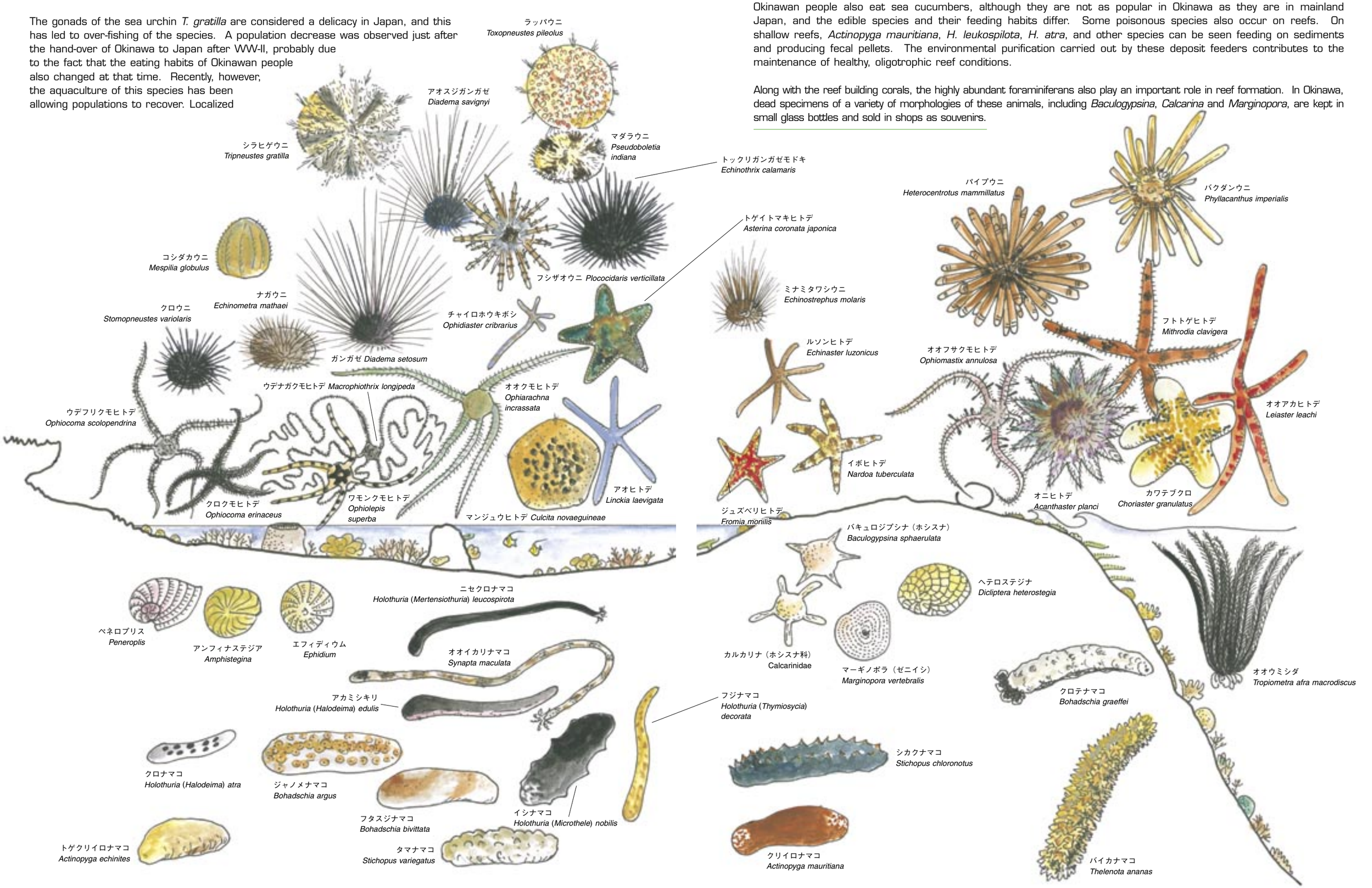
Coral reef organisms. Part II

Echinoderms, sea urchins, sea cucumbers, and ophiuroids are abundant in backreef lagoons and on the reef flat, and crustaceans, such as small crabs and shrimps, are the most abundant animals associated with pocilloporid or acroporid corals. Why do echinoderms and crustaceans flourish in the coral reef environment?

The gonads of the sea urchin *T. gratilla* are considered a delicacy in Japan, and this has led to over-fishing of the species. A population decrease was observed just after the hand-over of Okinawa to Japan after WW-II, probably due to the fact that the eating habits of Okinawan people also changed at that time. Recently, however, the aquaculture of this species has been allowing populations to recover. Localized aggregations of the sea urchins, *D. setosus* and *Heterocentrotus mamillatus*, which appear from crevices at night, also characterize the coral reef underwater scenery.

Okinawan people also eat sea cucumbers, although they are not as popular in Okinawa as they are in mainland Japan, and the edible species and their feeding habits differ. Some poisonous species also occur on reefs. On shallow reefs, *Actinopyga mauritiana*, *H. leukospilota*, *H. atra*, and other species can be seen feeding on sediments and producing fecal pellets. The environmental purification carried out by these deposit feeders contributes to the maintenance of healthy, oligotrophic reef conditions.

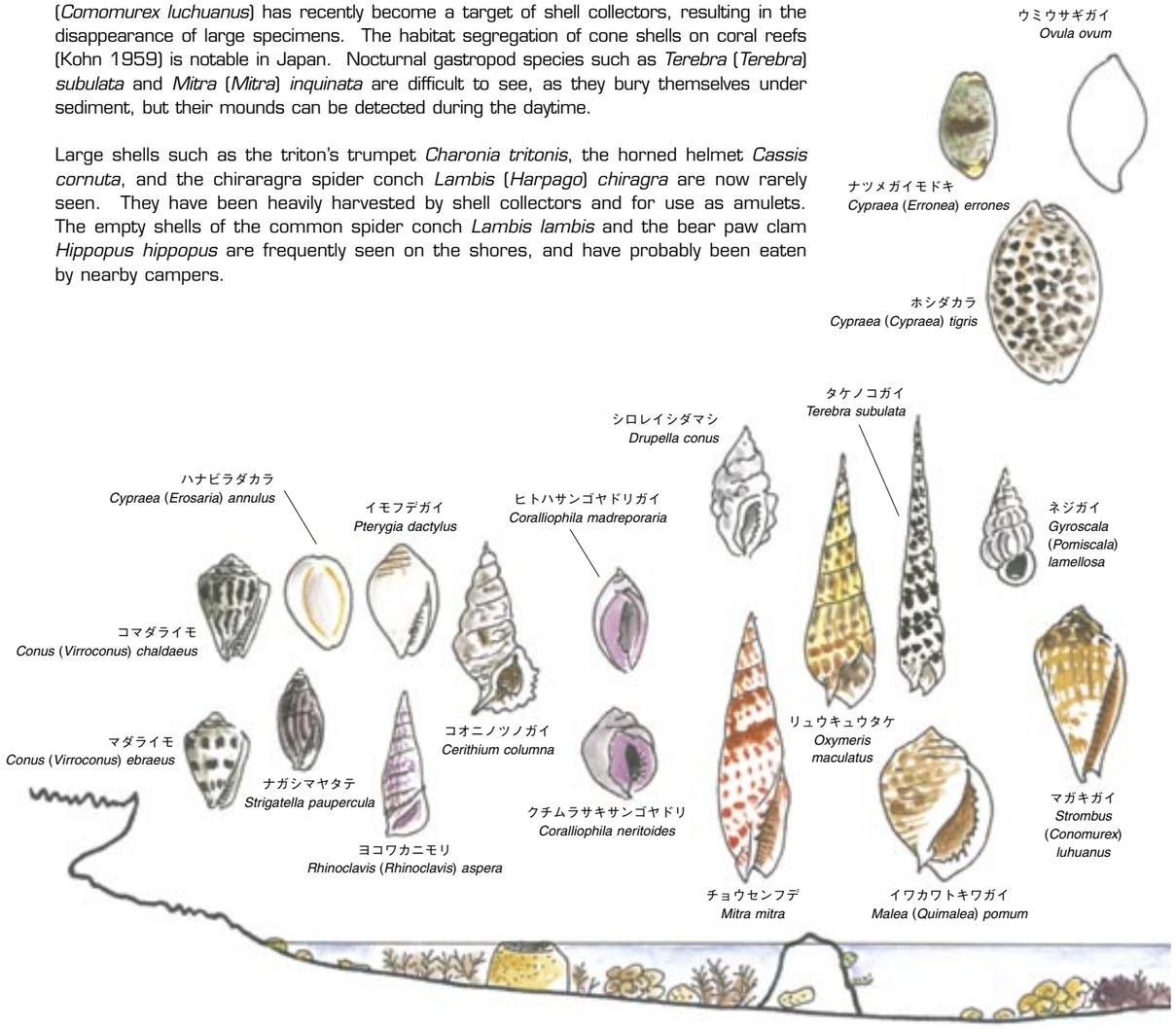
Along with the reef building corals, the highly abundant foraminiferans also play an important role in reef formation. In Okinawa, dead specimens of a variety of morphologies of these animals, including *Baculogypsina*, *Calcarina* and *Marginopora*, are kept in small glass bottles and sold in shops as souvenirs.



Coral reef organisms. Part III

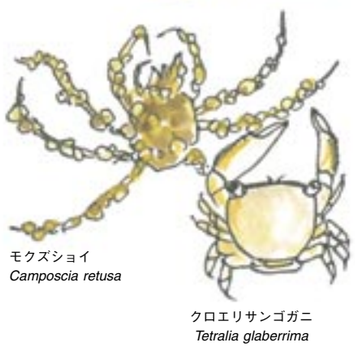
Crustacean and molluscan species are discussed in this section. The strawberry conch (*Comomurex luchuanus*) has recently become a target of shell collectors, resulting in the disappearance of large specimens. The habitat segregation of cone shells on coral reefs (Kohn 1959) is notable in Japan. Nocturnal gastropod species such as *Terebra* (*Terebra*) *subulata* and *Mitra* (*Mitra*) *inquinata* are difficult to see, as they bury themselves under sediment, but their mounds can be detected during the daytime.

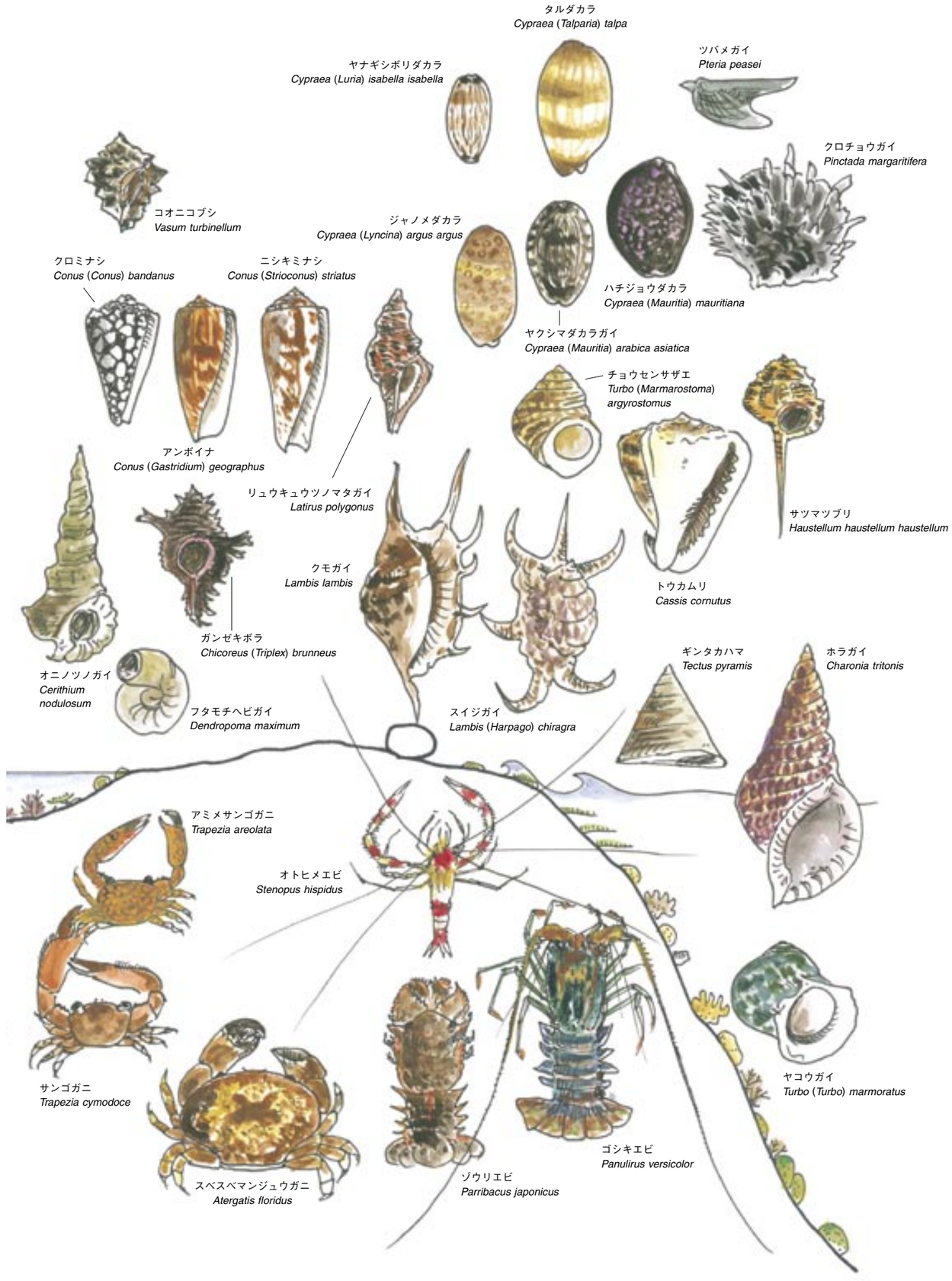
Large shells such as the triton's trumpet *Charonia tritonis*, the horned helmet *Cassis cornuta*, and the chiraragra spider conch *Lambis* (*Harpago*) *chiragra* are now rarely seen. They have been heavily harvested by shell collectors and for use as amulets. The empty shells of the common spider conch *Lambis lambis* and the bear paw clam *Hippopus hippopus* are frequently seen on the shores, and have probably been eaten by nearby campers.



Lobsters and *Scyllarides squamosus* occur on the reef slope and the reef edge. Living specimens are rarely sighted during the day, but are frequently caught along with other fishes and crabs in nets set at low tide near the reef edge.

The xanthid crab *Trapezia* spp., which is associated with the pocilloporid corals, has an interesting ecology. *Trapezia* spp. has been regarded as an obligate symbiont on pocilloporid corals, but the mechanisms of this symbiosis have not yet been clarified. Recently, specimens of *Trapezia cymodoce* were found on *Acropora* in the Kumamoto area (Tsuchiya and Nojima 2002), and other species of *Tetralia* have also been found on *Acropora* colonies. These interactions should be a topic for further research. Heterosexual pairs of *Trapezia* and of the shrimp *Alpheus lottini* have been observed on pocilloporid corals. Interactions among these obligate symbionts are interesting (Vannini 1985; Tsuchiya and Yonaha 1992). The obligate gastropod *Coralliophila neritoidea* and the goby *Paragobiodon* spp. are also commonly seen on pocilloporid corals.





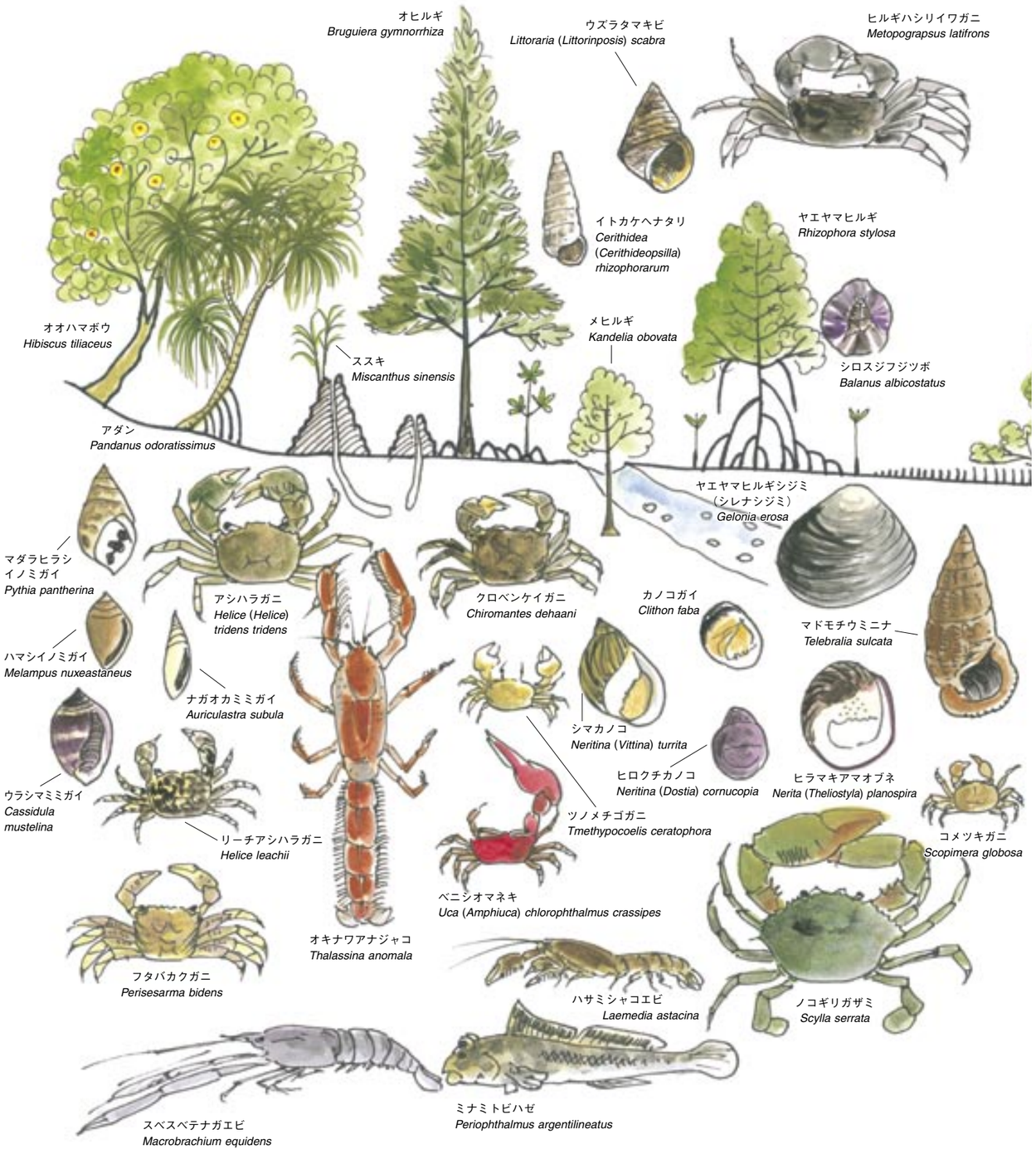
Communities in mangrove forests and neighboring tidal flats

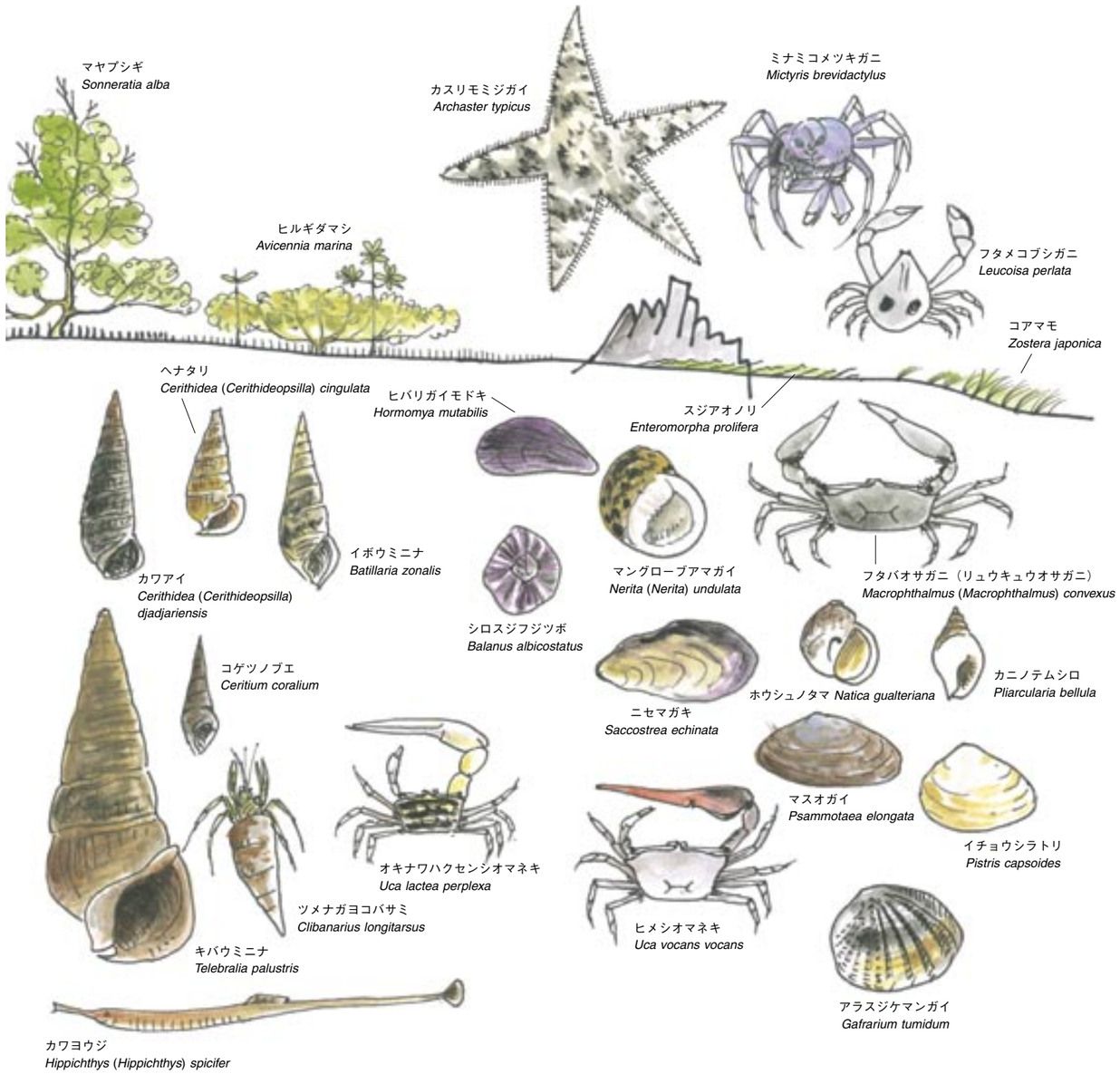
In Japan, mangrove forests typically consist of *Kandelia candel*, *Bruiguirella gymnorrhiza*, and *Rhizophora stylosa*. Recently, Japanese and Taiwanese specimens of *Kandelia*, the distribution of which was previously thought to extend as far as Kagoshima Prefecture (31°20'N), were re-examined morphologically and biochemically, and identified as a new species, *Kandelia ovobata* (Sheue *et al*. 2003). The true distribution of *K. candel* is now reported to include India, Thailand and Indonesia.

Several species of animal, including *Cassidula mustelina*, *Melampus castaneus*, and the littorinid *Littorinopsis scabra* inhabit mangrove trees, and the sesarmid crab, *Metopograpsus latifrons*, is found on the trunks. Sessile species, including the barnacle *Balanus albicostatus albicostatus* and the oyster *Crassostrea echinata*, attach their roots onto mangrove trunks. Large sandy-mud mounds, which can reach approximately 1 m in height, and are made by *Thalassina anomala*, can be seen around mangrove trees.

In the channels, the mud crab *Scylla serrata* is caught by traps, mainly for consumption. Some specialists use long rods with hooks to extract these crabs from their burrows. The gobies, *Periophthalmus vulgaris* and *P. cantonensis*, sometimes co-exist in Okinawa, making it the northern limit for the former species and the southern limit for the latter.

The mud creeper *Terebralia palustris* and large species of sesarmid crabs feed on the fallen leaves of mangroves. The feces that they produce are utilized as food by small benthic animals, such as fiddler crabs and small gastropods. Extraordinary aggregations of the fiddler crab *Uca perplexa*, and the soldier crab *Mictyris breridactylus*, can often be seen on tidal flats. The gastropods, *Batillaria zonalis* and *Cerithideposilla cingulata*, are also abundant.





Communities in seagrass beds

Seagrasses and seaweeds play an important role as primary producers and as sources of organic materials for coral reef organisms. Their role in offering a variety of habitats to small organisms can be likened to that of forests in terrestrial ecosystems. At low tide, fecal pellets produced by sea cucumbers and lug worms, mounds made by ghost shrimps, and siphons of bivalves can be seen; in addition, the sounds made by snapping shrimps can be heard. At high tide, many small fishes swim among the seagrasses, and the extrusion of sandy particles from the burrows of ghost shrimps can be seen.

The conservation of dugong (*Dugong dugon*) is a subject currently receiving much attention in Okinawa. Dugong are distributed throughout the Indo-Pacific, with large populations occurring in Papua New Guinea and Australia. Information about dugong is very scarce, but the conservation of the species is linked to the conservation of seagrass communities, as seagrasses form the major part of the dugong's diet. In recent years, the only place around Okinawa Island that dugong have been seen is in the Ryukyu Archipelago, and their numbers are thought to be extremely limited. This species has been designated a Natural Treasure and has been protected by several Japanese laws, as well as by the Washington Treaty.