

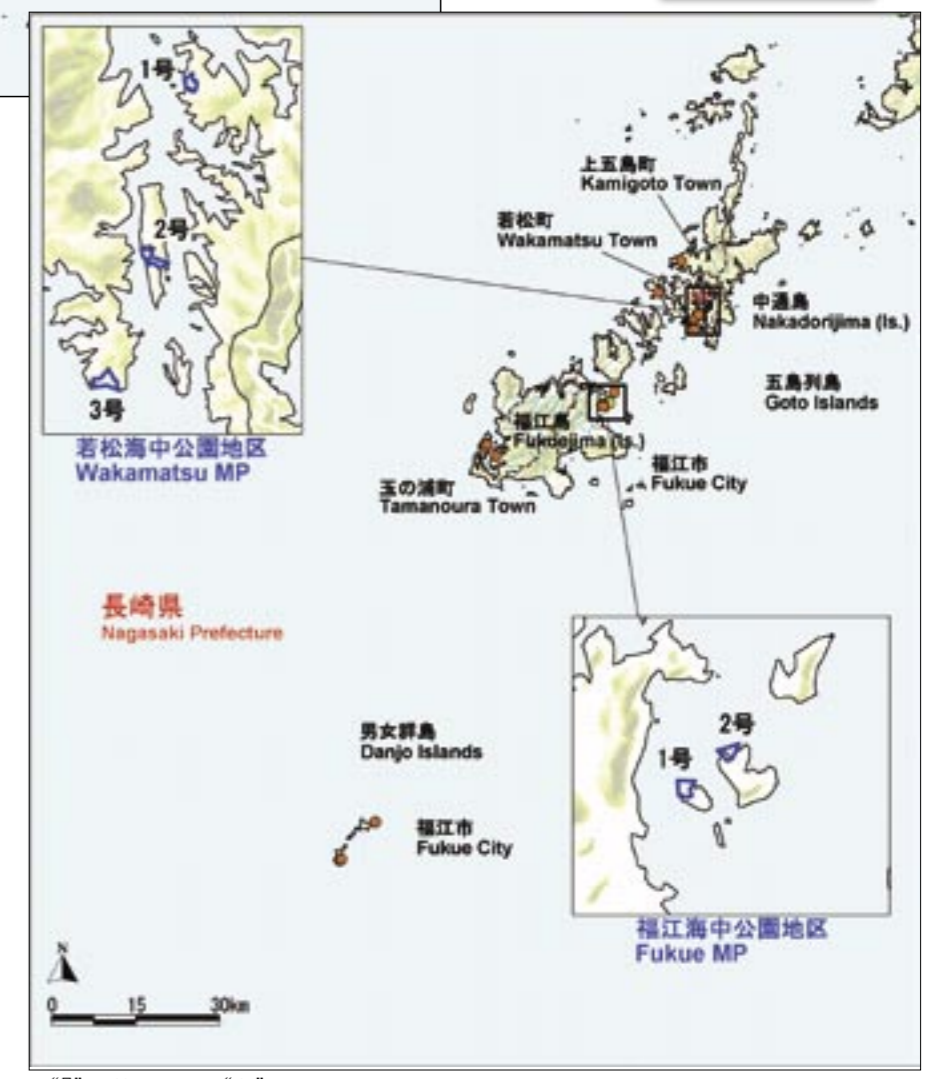
# 6-2-2 Sea of Japan (Map 6-2-2)

**Province:** Iki Islands, and Tsushima and Goto Archipelago: Nagasaki Pref.; Oki Islands: Shimane Pref. **Location:** Iki Islands and Tsushima Archipelago at north, and Goto Archipelago at east of Nagasaki City; Oki Islands at north of Matsue City **Features:** Highest latitude coral reef was reported on Iki Islands **Air temperature:** 15.5°C (annual average, at Tsushima) **Seawater temperature:** 19.4°C (annual average, at northeast off Tsushima) **Precipitation:** 2,132.7 mm (annual average, at Tsushima) **Total area of coral communities:** 10.9 ha **Protected areas:** Daisen-Oki National Park: whole Oki Islands; Saikai National Park: part of Goto Archipelago; Iki-Tsushima Quasi-National Park: part of Iki Islands and Tsushima Archipelago; Marine Park Zone: 3 zones in Iki Islands, 2 in Tsushima Archipelago, 2 in Goto Archipelago, 4 in Oki Archipelago, and 1 in Shimane Peninsula.

6-2-2-①



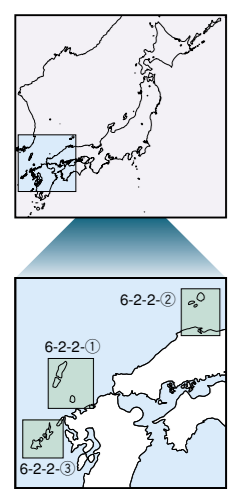
6-2-2-③



6-2-2-②



\* “号” on this map means “site”.



\* “号” on this map means “site”.

## a. Iki Islands

(Map 6-2-2-①)

Hiroya Yamano, Kaoru Sugihara,  
Tatsuo Nakai, Osamu Yamagawa

### 1 Corals and coral reefs

#### 1. Geographical features

The Iki Islands are composed of Oligocene to early Miocene sedimentary rocks (Katsumoto Group), covered by early to middle Pleistocene volcanic rocks, mainly basalt (Nagaoka 2001). Hermatypic corals are distributed on these rocks throughout the islands. At Kurosaki, a coral reef has formed (Eguchi and Fukuda 1972; Yamano *et al.* 2001). It is the highest latitude coral reef ever reported and described (Yamano *et al.* 2001c). The reef appears to be a wave-resistant structure and shows both topographical and ecological zonation. This reef was established at least 1400 years B.P., and is composed mainly of faviid corals and mud infillings. The size and thickness of the reef are estimated to be around 900 m<sup>2</sup> and at least 3 m, respectively. Nakai (1990) showed that high latitude reefs tend to occur in wave-protected areas, in contrast to those in tropical and/or subtropical areas, which develop well in high-energy wave-exposed locations. The location of the Kurosaki coral reef is in agreement with this suggestion. No coral reef formation is known from other sites around the Iki Islands.

#### 2. Coral distribution

Coral communities (mainly scleractinians) mostly occur inside small, turbid bays such as Honguu (Tsutsugata), Kurosaki (Isigataura), and Watarahigashi (Kouze, Itaura), all located on the western coast of Iki Island (Fig. 1). In these bays, massive faviids (*Cyphastrea*, *Favia*, *Favites*, and *Goniastrea*), foliose *Echinophyllia* and *Lithophyllon* dominate at 1–5 m depths. Some locally aggregated *Acropora* communities are also seen in these areas. Most of these coral colonies are large sized and in close proximity to each other. Thus, in these areas the local coral coverage is very high but the number of species is low. Depth zonation of different coral species has been described at Kurosaki (Eguchi and Fukuda, 1972; Yamano *et al.* 2001). Terrestrial sand/mud with coral

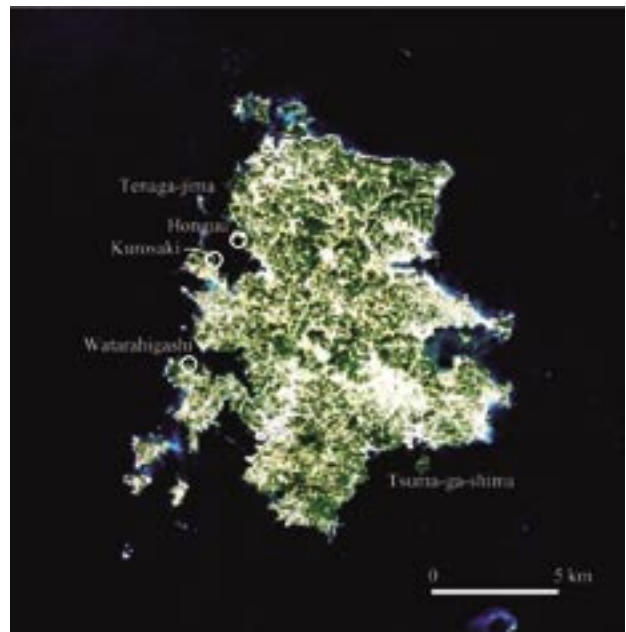


Fig. 1. Location of the coral communities investigated in the Iki Islands.

rubble, but no live corals, is found in the area 0–35 m from the shore (Fig. 2). Between 35 and 40 m from shore are raised topographic areas (1.5–2 m depth), dominated by *Caulastrea tumida* and *Favia speciosa*. *Echinophyllia echinata* and *Lithophyllon undulatum* occur on the outer reef slope (2–9 m depth), around 40–50 m from the shore (Fig. 2, Photo. 1, Appendix 1-7-Table 3). At Tenagajima and Tsumagashima there are shallow slopes (< 5 m depth) formed by basalt boulders that are inhabited by few corals but many species of macro-algae such as *Sargassum* spp. and *Ecklonia cava* (Fig. 1). Large faviid colonies (~50 cm in diameter) are scattered in the deeper areas adjacent to the slopes (5–8 m depth) where the substrate changes from boulder to sand.

Several reports have described coral distribution around the Iki Islands (Kimura 1965; Eguchi 1971b; Eguchi and Fukuda 1972). These reports were written during site selection procedures for marine park designation by Nagasaki Prefecture, and recognize 22 species of 19 hermatypic coral genera. Following extensive taxonomic revisions (Veron 1992c, 2000a, 2000b, 2000c) subsequent surveys have identified 39 species of 22 genera in the Iki Islands, including species recognized in our investigation during August–September, 2003 (Appendix 1-7-Table 4). Most of these species are widely distributed, from subtropical (reefal) to temperate (non-reefal) regions in Japan. *Caulastrea tumida*, *Favites russelli*, *Goniastrea australiensis*, *Platygyra contorta*, and *Oulastrea crispata* are common in the Iki Islands and in non-reefal areas

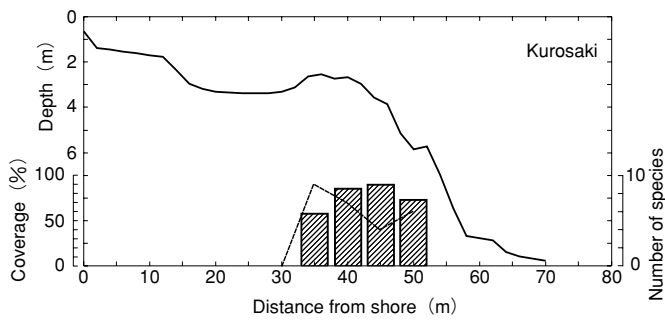


Fig. 2. Topographic profile (solid line), coverage (hatched bars), and number of coral species (dashed line) along the transect from shore to sea on the shallow slope at Kurosaki, Iki Island.

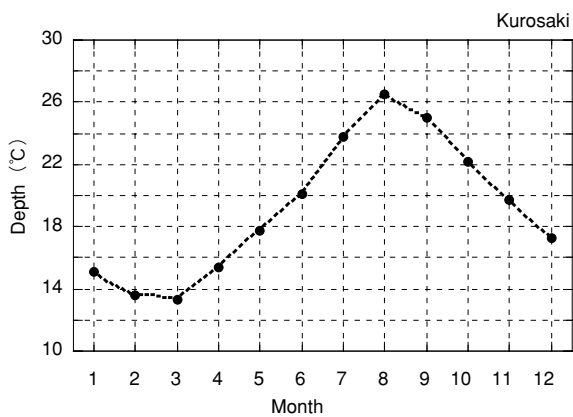


Fig. 3. Monthly mean sea-surface temperatures at Kurosaki, Iki Island (data averaged from 1986 to 2000 and provided by Tasaki Shinju Co. Ltd.).



Photo. 1. Large colonies of *Favia* spp. and *Echinophyllia* spp. on the shallow slope at Kurosaki, Iki Island. Note that *Favia* spp. were found on the shallower parts of the slope (A) while *Echinophyllia* spp. occurred at greater depths (B).

(Nishihira and Veron 1995). *Acropora tumida*, *A. pruinosa*, and *Alveopora japonica* were found only in non-reefal areas.

### 3. Water quality and physical environment

The mean annual water temperature for the seas surrounding the Iki Islands is 20°C, with the annual low in March (14°C) and the annual high in September (27.5°C; Natsukari and Takita 1972). Nearshore mean water temperatures at Kurosaki were 13.3°C and 26.2°C in March and August, respectively (Fig. 3). Water temperatures in March at Kurosaki are clearly well below 18°C, which has generally been accepted as the lowest temperature at which coral reefs can form.

### 4. Notable species and ecosystems

The coral reef at Kurosaki is acknowledged to be the world's highest latitude coral reef (Yamano *et al.* 2001). Corals are generally distributed on slopes shallower than 5 m in the Iki Islands, but a few corals are

found on the shallow slopes where macroalgal species such as *Sargassum* spp. and *E. cava* flourish. This suggests that the local distribution and abundance of most coral species in the Iki Islands depends mainly on competitive exclusion between corals and macro-algae (Johannes *et al.* 1983; Veron 1992c). Barnacles, bivalves (mainly *Saccostrea* and *Mytilus*), and gastropods (such as *Serpulorbis*) are attached not only to dead but also to live coral colonies. Large numbers of *Diadema setosum* and *D. savignyi* are found on and around living coral colonies in Kurosaki. Thus, high-latitude corals appear to have competitive relationships not only with macroalgae but also with other invertebrates.

## 2 Situation of usages

### 1. Tourism

Operators in the town of Gounoura run sea kayak tours

around Kurosaki coral reef. Otherwise, there are few if any options for tourists interested in local coral reef communities.

## 2. Fishery

Pearl culture occurs in some bays, including Kurosaki. Apart from this, there are no fishing activities associated with corals and coral reefs in the Iki Islands.

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## 3 Threats and disturbances

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Most coral colonies are large, and few colonies appear to have recently died. This indicates that there have not been any mass bleaching events or outbreaks of coral predators in recent years. Around Iki Island, corals are widely distributed in certain bays where relatively low-impact pearl culture operations have been set up. This may have shielded these coral communities from higher-impact human disturbances such as fishing and the construction of ports. However, sedimentation may be a problem. Red soil runoff is seen during the rainy season in some bays, in some cases reducing transparency to ~1 m. The impact of this on shallow-water fauna, including corals, is a matter of concern, especially as red sedimentation has been noticed on some live coral colonies.

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## 4 Monitoring and conservation

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Red soil runoff appears to be related to the development of farms, and to the maintenance and improvement of roads. Prompt action should be taken to preserve coral communities and their habitats, for example, by the construction of drainage ditches or ponds to filter out the soils. The highest-latitude coral reef should be designated a marine protected area, as should locations at Watarahigashi and Honguu, where rich coral communities occur. Of great concern in terms of conservation is the fact that neither visitors to, nor residents of, the Iki Islands (and the Tsushima Islands) are aware of the significance of local coral communities or the coral reef. This ignorance may result in the decline of the coral communities through careless development. An increase in levels of public awareness in this respect would be very helpful.

## b. Tsushima Archipelago

(Map 6-2-2-①)

Kaoru Sugihara, Hiroya Yamano

### 1 Corals and coral reefs

#### 1. Geographical features

The Tsushima Archipelago are composed of Oligocene to early Miocene marine sedimentary rocks (Taishu Group), and Miocene granite and hornfels (Nagaoka 2001b). Ria coasts are common in the Tsushima Archipelago, especially in Asou Bay, which is in the central part of Tsushima Archipelago. Hermatypic corals are found throughout the islands (Fig. 1), and achieve high coverage in Kaseura and Senoura. Some accumulated carbonate structures are found in Senoura (Eguchi 1973), but these are not regarded as coral reef formations because of their small scale. No other coral reef-like formation has been reported from the Tsushima Islands.

#### 2. Coral distribution

Originally, 26 coral species of 20 genera were reported from the Tsushima Archipelago (Kimura 1965; Eguchi 1973). However, similar to the situation in the Iki Islands (Eguchi and Fukuda 1972), the identification of many of these species was affected by Veron's (1992c) extensive taxonomic reclassification of corals. Recent surveys utilizing the latest taxonomic opinion (Veron 2000a, 2000b, 2000c) have identified 38 species of 23 genera, including species found in our investigation during December, 2002 (Appendix 1-7-Table 5).

Corals (mainly scleractinians) are mainly distributed in small, shallow, and turbid bays that are sheltered from waves, especially Asou Bay. Species diversity of corals is high on the slopes at bay mouths (1-5 m depth). Coral communities in Kaseura and Senoura (Fig. 1) are composed mainly of *Caulastrea tumida*, *Echinophyllia aspera*, *Favia speciosa*, and *Lithophyllon undulatum*, colonies of which extensively occupy the slopes, forming several patches (Photo. 1). As depth changes, so do the dominant coral species. At Kaseura, small colonies of *Oulastrea crispata* are scattered on the basal rock

near the shore at a depth of 1 m, while *F. speciosa* and *E. aspera* are abundant at depths of 2.0-2.5 and 2.5-5.0 m, respectively (Appendix 1-7-Table 6). At Senoura, the coverage of *C. tumida* is high at depths of 1.0-1.5 m, while high coverage of *F. speciosa* and *L. undulatum* occurs at depths of 1.5-2.0 m. *E. aspera* is found in areas ranging in depth from 1.5 to 6.0 m, occupying the slope below 2 m depth (Appendix 1-7-Table 6). The distribution patterns of coral communities are similar in these areas, in that while coverage is high, species diversity is low (Fig. 2). Dense populations of *Acropora tumida* occur at Ohtaura and Oura on the southeastern coast of Tsushima Archipelago (Fig. 1).

Comparison of coral communities in the islands of Tsushima and Iki shows that 25 species in 18 genera are common. However, a limited number of sites have been surveyed at both islands, so the number of identified and common species is expected to increase in future surveys. Other common features of coral communities at these two islands are: 1) coral communities are found on shallow slopes (1-5 m depths) in sheltered and turbid bays; 2) coverage of these communities is high but the number of species is low; 3) *F. speciosa*, *E. aspera* (*E. echinata* in Iki Islands), and *L. undulatum* are dominant species, while *Acropora* spp., which dominate in the Ryukyu Islands, are rare; and 4) most of the colonies are large, some more than ten centimeters in diameter. Similar communities have not been reported from any other regions in Japan. Of particular interest is the fact that habitat ranges (in terms of depth) may be very different for coral species off the islands of Tsushima and Iki, relative to more tropical locations. For example,



Photo. 1. *Favia* spp., *Echinophyllia aspera*, and *Lithophyllon undulatum* found at < 5 m depth on the shallow slope at Senoura, the Tsushima Islands.



Fig. 1. Locations of the coral investigated in the Tsushima Archipelago.

most species found at < 2 m depth at Tsushima and Iki never occur at this depth in other, non-reefal regions in Japan, such as Amakusa in Kyushu, Kushimoto in the Kii Peninsula, Suruga Bay facing the Izu Peninsula, and Tateyama in the Boso Peninsula (Veron 1992c; Minegishi and Ueno 1995; Nojima and Yeemin 1999; Hagiwara 2003). In a further example, *Favia* spp., *Echinophyllia* spp., and *L. undulatum*, which at Tsushima and Iki are distributed on slopes shallower than 5 m, are found mostly at depths > 5 m in the Amakusa and Kushimoto regions, and on still deeper reef slopes in the Ryukyu Islands (Nakamori 1986; Nishihira and

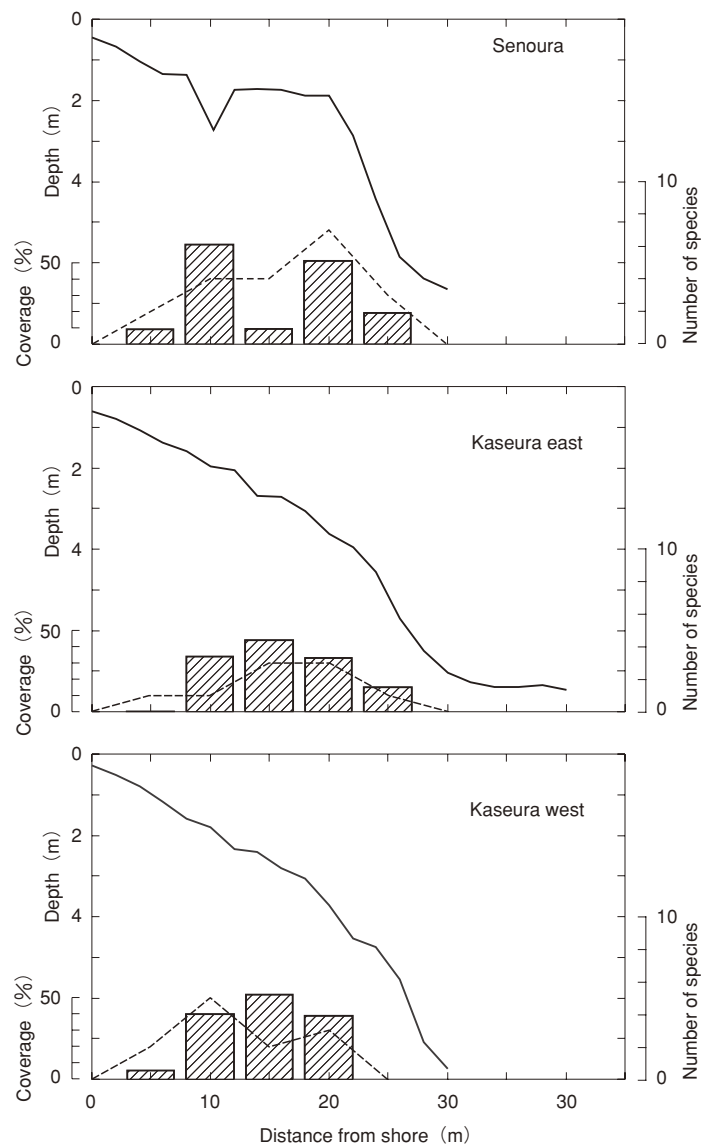


Fig. 2. Topographic profile (solid line), coverage (hatched bars), and number of coral species (dashed line) along the transect from shore to sea on the shallow slope at Senoura and Kaseura, Tsushima Archipelago.

Veron 1995; Nojima and Yeemin 1999). These latitudinal differences in the depth distribution of coral communities are probably generated by latitudinal gradients in physical/chemical environmental characteristics such as temperature, light intensity, water motion, and turbidity, etc. (Done 1982; Rogers 1990; Veron and Minchin 1992). However, quantitative data are scarce for high-latitude communities and further studies are needed.

A similar coral community, including 55 species of 33 genera, is fossilized in the Holocene beds of Numa in Tateyama, Chiba Prefecture (Veron 1992b) (Chapter

6-2-1). The physical environment that formed this fossilized community may have been similar to that of the present-day Tsushima and Iki islands. Yamano *et al.* (2001c) suggested that dominant species (genera) might be reflective of the mean low sea surface temperatures (SSTs) of their habitats. The Iki Island coral reef is composed mainly of massive *Favia*, while reefs in the subtropical Ryukyu Islands are formed mainly by tabular *Acropora* (Kan *et al.* 1995). Although fossil coral communities dominated by *Favia* have been found in deposits off Miyako Island in the Ryukyu Islands, these formed during the last glacial maximum (around 21,000 years ago; Omura and Tsuji 1997), when the predicted winter SST for this area was 15–18°C (Li *et al.* 1997). This value is somewhat higher than, but certainly similar to, present-day values for the islands of Tsushima and Iki (Natsukari and Takita 1972; Natsukari *et al.* 1973; Yamano *et al.* 2001). In summary, the coral communities of Tsushima and Iki will help us to understand relationships between environmental gradients and coral reefs through the late Holocene, and to estimate Quaternary SST fluctuations through glacial-interglacial cycles.

### 3. Water quality and physical environment

Despite the high latitude, the Tsushima Current from the East China Sea keeps the Tsushima Islands relatively warm. The mean annual water temperature for the seas surrounding the islands is 19.5°C, with the annual low in March (13°C) and the annual high in September (27°C; Natsukari *et al.* 1973). Periodic winter winds from the north lower the islands' air temperature, relative to that experienced at a similar latitude on Honshu (Japan's main island). Snow is rare in this area (Tsushima Branch Office, Nagasaki Prefectural Government 2002).

The steep topography of Tsushima Archipelago means that the river catchment area is small, and terrestrial inflows happen abruptly after rainfall. Corals in Asou Bay are considerably influenced by frequent terrestrial inflows.

### 4. Notable species and ecosystems

Coral communities around the islands of Tsushima and Iki, near the northern limits of coral habitat in the Northwestern Pacific, are biologically important for evaluation of the reproductive and growth capabilities of corals under climatic stress. They would also serve as useful materials for discussing reef responses to environmental change, as previously noted.

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## 2 Situation of usages

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### 1. Tourism

SCUBA divers visit the *A. tumida* communities at Ohtaura and Oura.

### 2. Fishery

Pearls are cultured in some bays. Apart from this, no fishing activities are associated with coral communities or coral reefs.

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## 3 Threats and disturbances

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Coral distribution is decreasing in some small bays owing to destruction and sedimentation that has occurred during the construction of fishing ports. Some communities have been degraded by red soil runoff as a result of road construction works. In some inlets at Senoura, large numbers of live coral colonies have already been reclaimed or removed during shore protection works. Anthropogenic pollutants, including oil, are sometimes seen flowing down rivers or leaking from fishing boats into the sea.

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## 4 Monitoring and conservation

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Our knowledge of coral distribution in Tsushima Archipelago is still limited; future surveys are expected to increase the number of known coral species around the islands, especially in the Asou Bay area, where there are many small inlets. Most coral habitats are close to villages, fishing ports and/or areas where pearls are cultured. Some of those habitats have disappeared as a result of harbor construction and repair. Immediate conservation measures are necessary to protect the critically vulnerable coral communities of the Tsushima Archipelago; such measures should include the establishment of marine protected areas.

## c. Oki Islands and Goto Archipelago

(Maps 6-2-2-②, ③)

Hiroya Yamano

In a survey of hermatypic corals of the Goto Archipelago, Nagasaki Prefecture, Eguchi (1971b, 1975) reported 31 species of 20 genera in the sea area off the town of Goto, and 31 species of 20 genera in the Kami-Goto Islands. Off the islands of Hirado and Tsukumo, in Shimabara, 22 species of 16 genera were reported (Eguchi 1975). As has occurred at the islands of Iki and Tsushima, these species have since been taxonomically revised and further investigation is needed to establish true species numbers.

The only hermatypic coral species Nomura *et al.* (1994) identified from the Oki Islands (Shimane Prefecture) were *Alveopora japonica*, *Psammocora profundacella*, and *Oulastrea crispata*. This indicates that species richness decreases from the Goto Archipelago through the Oki Islands to the islands of Iki and Tsushima, in accordance with the latitudinal decrease in water temperature. Veron and Minchin (1992) have also observed this for the Japanese Pacific coasts. Coral reef formation has not been reported from any of the islands of the Oki Islands and Goto Archipelago.