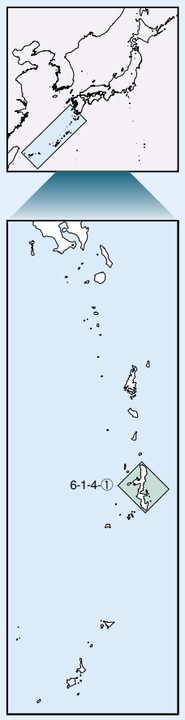
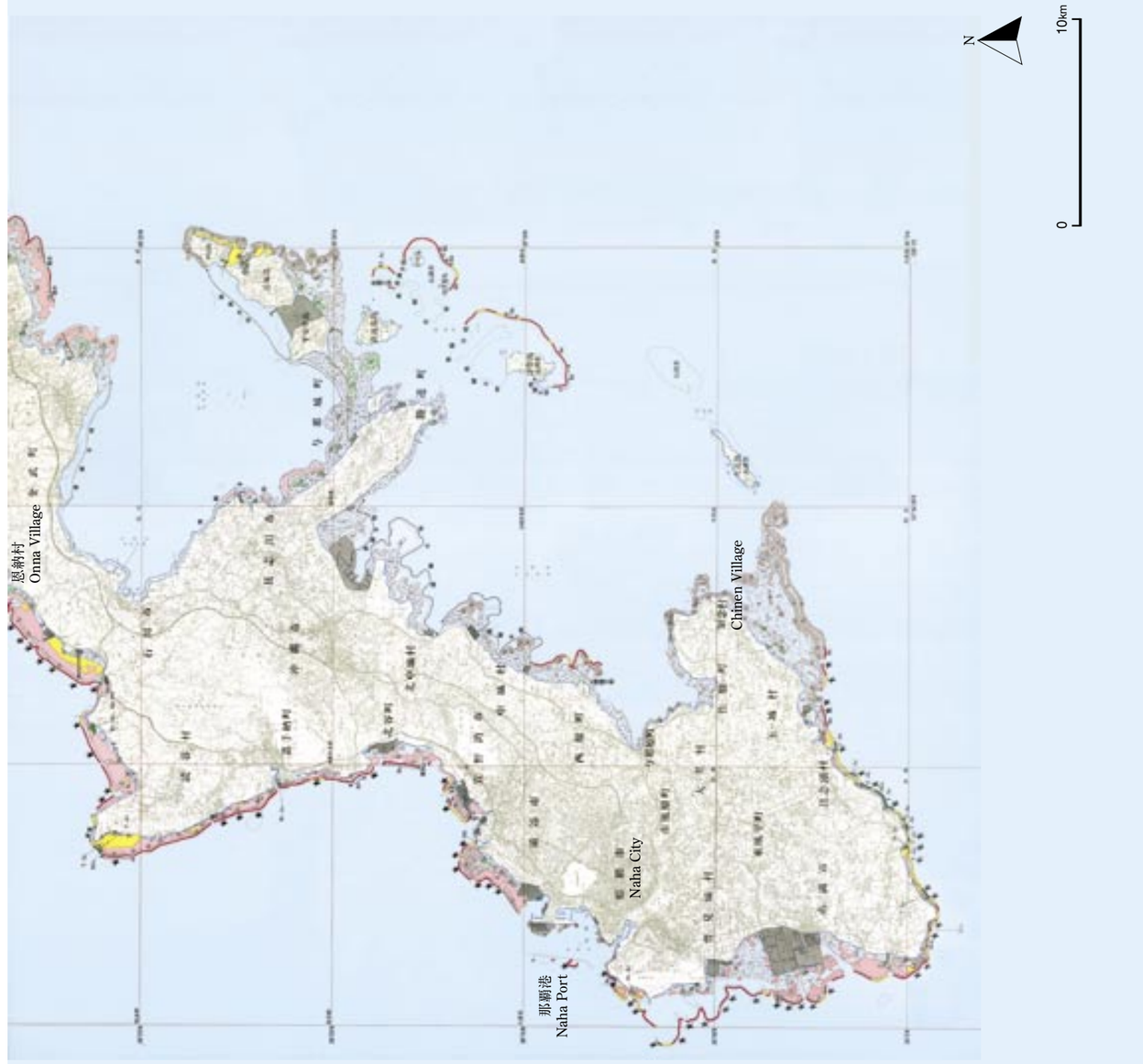
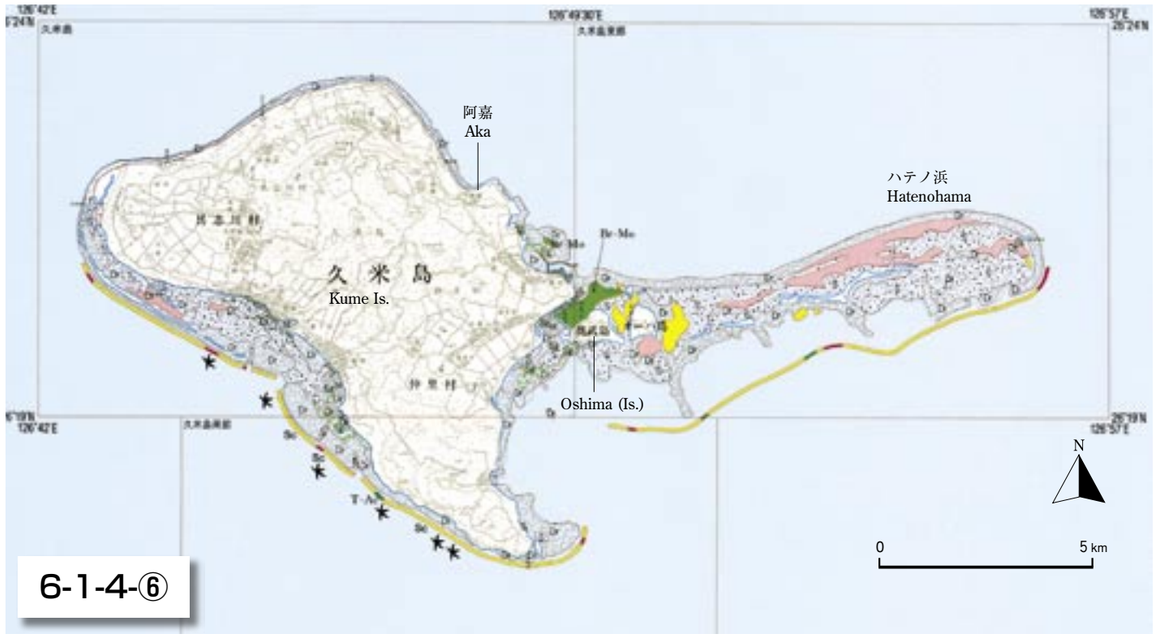
6-1-4 Okinawa Islands
(Map 6-1-4)

Province: Okinawa Prefecture **Location:** Okinawa Is. and neighboring islands, including; Iheya, Izena, Aguni, Tonaki, Kume Is., and Kerama Islands. **Air temperature:** 22.7˚C (annual average, in Naha City) **Seawater temperature:** 25.0˚C (annual average, at off Naha) **Precipitation:** 2,036.7 mm (annual average, in Naha) **Total area of coral communities:** 6,980 ha **Total length of reef edge:** 382.2 km **Protected areas:** Okinawa Kaigan Quasi-National Park: centering on west coast of Okinawa Is. and whole Kerama Islands; Marine Park Zones: 1 zone in Okinawa Island and 2 zones in Kerama Islands.

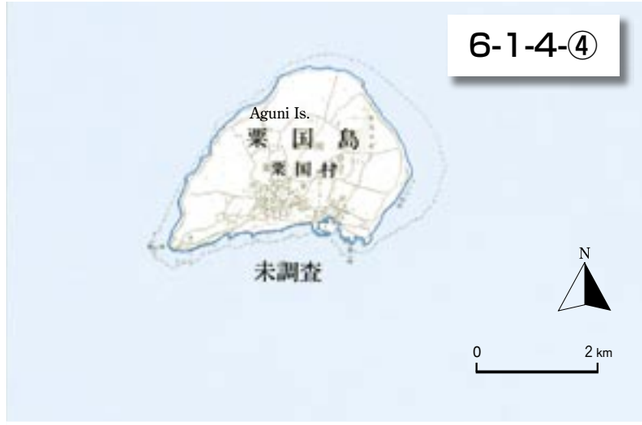
6-1-4-①



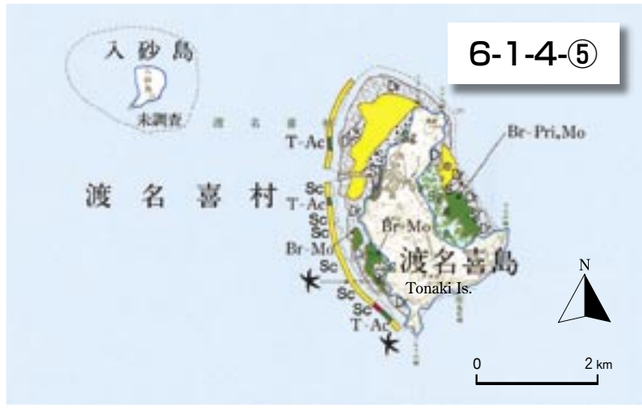




6-1-4-⑥

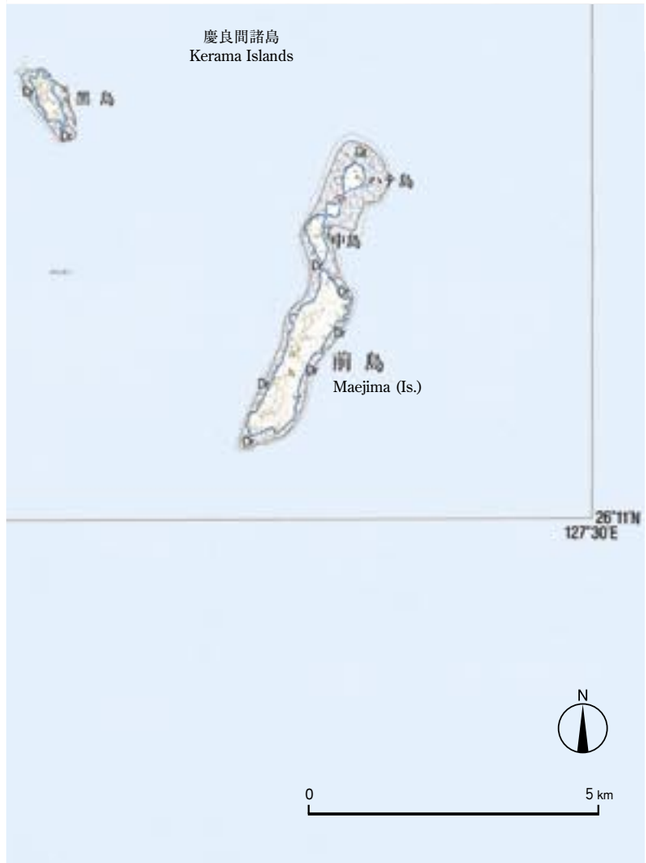


6-1-4-④



6-1-4-⑤

6-1-4-③



a. Okinawa Island

(Map 6-1-4-①)

Kazuhiko Sakai

1 Corals and coral reefs

1. Geographical features

Most of the coral reefs around Okinawa Island (hereafter Okinawa) are fringing and patch reefs, which have developed adjacent or close to the Okinawa. However, on the southeastern coast, patch reefs have developed several kilometers offshore. forming barrier reef like.

2. Coral distribution

Okinawa is in the direct path of the Kuroshio Current, which sustains more than 340 scleractinian corals, and eight non-scleractinian corals at a relatively high (26°N) latitude (Nishihira and Veron 1995). The number of the scleractinian coral species on Okinawa is three times more than that recorded at similar latitude on the Great Barrier Reef (Veron 1993; Nishihira and Veron 1995). To date there is only one unique coral species (an undescribed species of *Fungia*) reported on Okinawa (Nishihira and Veron 1995).

Corals have been gradually decreasing on Okinawa since the 1970s, mainly because of the crown-of-thorns starfish (*Acanthaster planci*) predation (Sakai and Nishihira 1986). Dramatic reductions in coral abundance also occurred in 1998 in association with the thermal stress event. For example, Loya *et al.* (2001) compared coral community structure between 1997 and 1999 on a fringing reef at southeast coast of Sesoko Island, northwestern Okinawa. They showed that coverage of coral communities (including hard and soft corals) decreased by 85 % because of the 1998 mass-bleaching event (Fig. 1). There was little apparent recover 5 years later (in 2003). A survey by the Conservation Division of Okinawa Prefecture (2003) revealed that only 2 of 80 surveyed sites (Minna-jima and Ie-jima Island) supported coral cover > 25 % (Fig. 2). A detailed examination of coral communities at 18 stations along the western coast of Okinawa in 2003 showed that percent cover of corals was less than 5 % at all the stations (Sakai, unpublished data). Although there were numerous *Acropora* recruits after 1998 mass-bleaching event, and exceeded 20 colonies per m^2 at some stations, survival was low and was reduced to less than 10 per m^2 in 2003. At these stations, *A. planci* was common and appeared responsible for the high mortality rates after bleaching (Photo. 1).

Coral species diversity was also reduced in 1998. Loya *et al.* (2001) showed that the number of coral species decreased by 61 % on the fringing reef of Sesoko Island because of the mass-bleaching event (Fig. 1). Mortality of branching corals was much higher than non-branching corals (Loya *et al.* 2001). Notably, the author has not found any colonies of *Seriatopora hystrix* and *S. caliendrum* around Okinawa since 1998, and fears a high probability of local extinction of these species.

3. Water quality and physical environment

Water quality is declining around Okinawa due to human activities. Terrestrial red soil run-off to coral reefs had been evident since at least the 1970s. Eutrophication, caused mainly by agricultural runoff and domestic sewage, has also recently increased. Low seawater transparency near Okinawan cities appears related, in part, to an increase in phytoplankton. Benayahu (1995) suggested that an increase in the percent cover of soft corals around Okinawa is due to a deterioration in water quality – the percent cover of soft corals is actually high near cities, for example Sunabe (central west coast).

4. Notable species and ecosystems

There have been some sightings of the endangered dugong species, *Dugong dugon*, on the northeastern coast of Okinawa (Photo. 2). An endemic species of fish, *Scartelaos histophorus*, is found on the tidal mud flats of Nakagusuku Bay (central east coast). It is highly probable that their habitats are threatened, as are the coral communities, considering prospective (rapid) development and land reclamation.

2 Situation of usages

1. Tourism

There are more than 130 dive shops on Okinawa. Some dive operators have changed their destination to the Kerama Islands, because coral reefs around Okinawa have degraded. For non-diving tourists, glass-bottomed

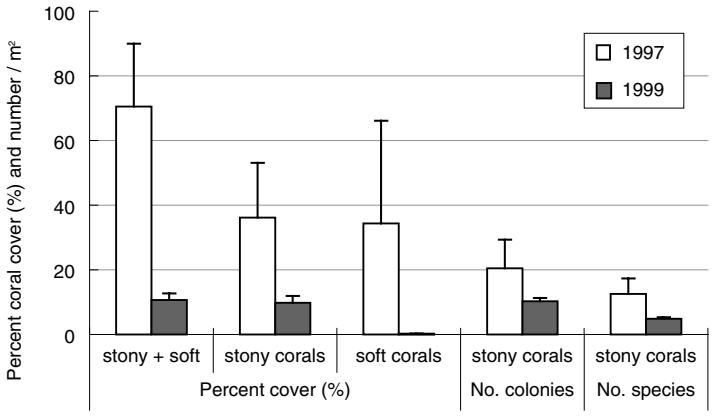


Fig. 1. Changes in coral coverage of stony and soft corals and the number of colonies and species between 1997 and 1999 on a fringing reef flat at southeast coast of Sesoko Island, northwestern Okinawa (from Loya *et al*. 2001). The error bar represents standard deviation.

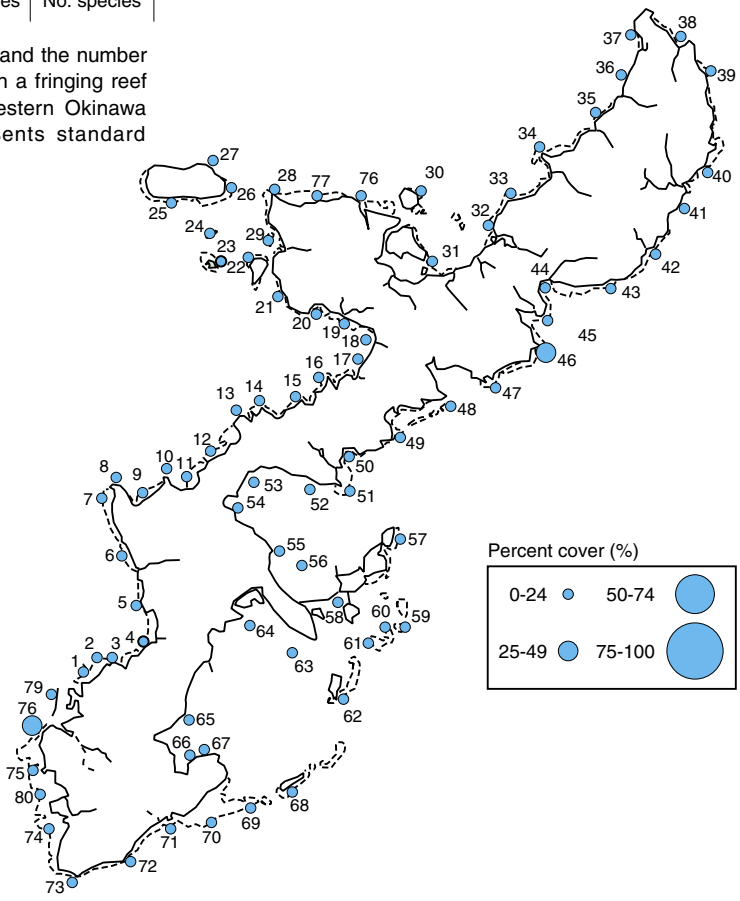


Fig. 2. Percent cover of hermatypic corals at 80 sites around Okinawa Island in a survey of 2003 (Conservation Division Department of Cultural & Environmental Affairs, Okinawa Prefectural Government).

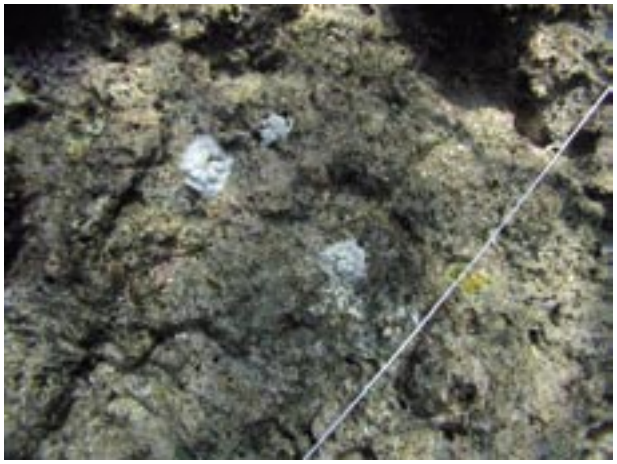


Photo. 1. Juvenile *Acropora* colonies recently (< 2–3 days) eaten by *Acanthaster planci* (3 white skeletons in the middle) on a reef off Onna Village in 2003 (an individual *A. planci* starfish was inside the burrow at the upper right), while one live juvenile *Acropora* colony can be seen at the center right of the photo.

Photo. 2. A Dugong (*Dugong dugon*) observed at off Abesaki, Kayo, Nago City (July 3, 2003). (photo provided by Ministry of the Environment, Government of Japan).

boats are available in Naha harbor, Chinen Village and Onna Village, and an underwater observatory is popular at Nago City. Recently, coral transplantation projects have attempted to restore the damaged reefs largely organized by local fisheries cooperatives and diving shop associations.

2. Fishery

There are 23 fisheries cooperatives on Okinawa. Coastal fisheries in coral reef areas were active in the past but have recently declined. Today, some traditional coastal fisheries are barely active. In contrast, aquaculture of fishes and macroalgae (seaweed) have recently increased.

3 Conservation

1. Crown-of-thorns starfish

Local fishermen and divers have been exterminating *A. planci* with support from the Okinawa Prefecture and the Ministry of the Environment. Notably, the Onna Village Fisheries Cooperative has been exterminating large numbers of *A. planci* for well over 10 years.

2. Sedimentation

Red soil run-off, from large construction works, has been recently reduced since the successful enforcement of the Okinawa Prefecture Red Soil Erosion Prevention Ordinance (http://www.c-okinawa.co.jp/eikanken/index.htm). However, run-off from agricultural fields remains a problem.

b. Kerama Islands

(Map 6-1-4-②)

Kenji Iwao

1 Corals and coral reefs

1. Geographical features

Some 30 islands make up the Kerama Islands, 20–40 km west of Okinawa (Fig. 1). There are two administrative districts divided by the Kerama Straits, Zamami Village in west and Tokashiki Village in east.

From the distribution of Japanese cedar and Japanese cypress fossils in the rock stratum, it is thought that the Kerama Islands were part of a mountain range that extended to (northern) Okinawa and exceeded 1500 m above sea level in the Pliocene (1.5 million years ago). Well developed coral reefs formed around Okinawa 600,000–200,000 years ago, and remain as uplifted Ryukyu limestone. This limestone layer in Kerama Islands, however, is about 80 m below sea level, because the Kerama Islands have subsided (via diastrophism). Subsidence resulted in a mountain range remaining above today's sea level – the tops of those mountains are the Kerama Islands (Kizaki 1992).

2. Climate and oceanography

Akajima, central Kerama Islands, shows air temperatures that do not fall below 10°C, even in winter, with highs around 37°C in summer (July–August), and a monthly average of 28.9–31.9°C. Seawater temperature is lowest in February–March, but does not fall below 20°C, and is highest in July-August at 27.1–29.6°C (note: the water temperature was exceptionally high in August 1998, when the monthly average was recorded at 30.4°C.) Typhoons are common, and are often experienced even in early summer. Summers have extreme oceanographic conditions with about five typhoons approaching every year, bringing high waves, wind and rain, followed by calm intermittent periods. From October to April, the northern monsoon brings strong north winds and large swells (Hayashibara 1995; Iwao 2001).

3. Coral distribution

There are approximately 248 hermatypic coral species found on Akajima and the surrounding Kerama Islands (59 genera and 14 families) (Hayashibara 1995)

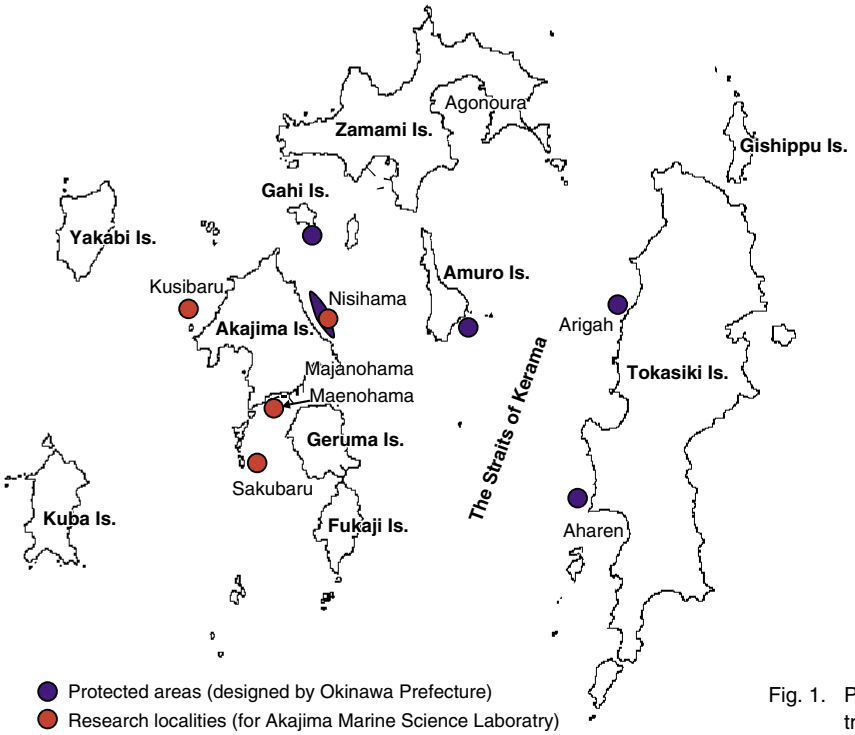


Fig. 1. Protected areas and survey localities using belt transects.

– or 62 % of the species recorded in Japan (Veron 1992). Considering their relatively small size the Kerama Islands are extremely rich in coral fauna (Hayashibara 1995).

The northern coast of Zamami Island supports spur and grooves and a tabular *Acropora* community, which used to be more extensive before the 1998 bleaching event and a more recent outbreak of the crown-of-thorns starfish (*Acanthaster planci*). The southwestern coast of the island supports high diversity, and Agonoura Bay, in the southeast island, is said to support unique coral communities but a satisfactory survey has not been conducted (Fig. 1).

Kushibaru, on the northwestern coast of Akajima, also has extensive spur and groove systems and large tabulate *Acropora* colonies from reef edge to 4–6 m down the reef slope (Photo. 1). Again, recent *A. planci* predation has reduced corals. Nishihama, on the eastern coast, supports diverse coral assemblages on a shallower slope. Maenohama, on the southern coast, supports artificial breakwaters about 100 m offshore; the sand bottom is scattered with sea grasses and rocks supporting massive faviids and branching *Montipora*.

Mass coral spawning has been observed annually on Akajima; spawning occurs in summer from May to September. Many *Acropora* (Photo. 2) and *Montipora* species spawn in May–June, *Merulina* in July, and some *Favia* in August–September.

'Healthy' coral communities are common on the west coast of Tokashiki Island. Especially in the two conservation areas where branching and tabular *Acropora* are dominant, showing in places more than 90 % coverage. The south coast receives most of the wave energy and supports few corals – mainly *Pocillopora* species. The east coast is also strongly affected by predominate wind and waves from the east, but branching and tabulate *Acropora* colonies are more typical in the bay area. The northeastern coast supports patches running perpendicular to the shore, with corymbose *Acropora* and alcyonaceans (soft corals and sea fans). The northwest coast supported the most diverse and luxuriant *Acropora* communities in the Kerama Islands, until 1998 coral bleaching and recent *A. planci* predation.

Photo. 1. Extensive spur and groove systems and large tabulate *Acropora* colonies form the reef slopes in Kerama Islands.

Photo. 2. Spawning of branching *Acropora* in Kerama Islands

The east coast of Gishippu Island, adjacent to Tokashiki Island, supports massive scleractinian corals and alcyonaceans. The west coast of Gishippu Island is comparatively shallow, supporting mainly *Porites cylindrica* and *Echinopora lamellosa* colonies, while the eastern and northwestern coast of Yakabi Island has many colonies of *Heliopora coerulea* (blue corals).

4. Notable species and ecosystems

Three hundred and sixty fish species, about 1,640 invertebrate species, including hermatypic corals, and about 220 seaweed species have been recorded in the Kerama Islands to date, but many groups of organisms have not yet been surveyed (Ohba 1995; Iwao 2003). Green turtles, loggerheads, and hawksbill turtles lay eggs on the beaches in summer, and are often encountered while diving. While the Kerama Islands are famous for their coral reefs, humpback whales (*Megaptera novaeangliae*) are very common in January to April, since they use the Kerama Islands as their breeding ground (Photo. 3).

On the land, 620 species of flora have been recorded, and the Kerama deer and other many animals inhabit. Kerama deer is a subspecies of the Japanese deer, and it lives only in the Kerama Islands. It is smaller and blacker than Japanese deer. The deer population on Akajima in 1970 was about 10, but has since increased to 130 in 1995. The deer are fully protected on some islands as a natural treasure of Japan (Editorial Board Zamami Village History 1989).

2 Situation of usages

1. Tourism

The diving industry flourishes here because of the rich marine life. There are 43 diving businesses in Zamami village and 14 in Tokashiki village, and even more for accommodation. Moreover, the number of tourists who enjoy sea kayaking has increased in recent years. While fishing was the main source of income in the past, now more than 80 % of the residents are engaged in tourism.

2. Fishery

From 1900 until the beginning of World War II, the skipjack fishery flourished, but declined during and after the war. Now, most skipjack catches are consumed locally. While swordfish, tuna, and skipjack are caught and consumed locally using lines, spinefoot (*suku*) are caught locally using gill nets in summer. In addition, local residents collect shellfish and octopus by scouring the reef flat at ebb spring tide.

3 Threats and disturbances

1. Change in coral communities

According to a coral survey using belt transects (explained later) at four localities on Akajima in October 1998, coral coverage was 35 % (219 colonies) at Kushibaru (northern cost), 34 % (565 colonies) at Sakubaru (southwestern coast), 29 % (275 colonies) at Maenohama (southern coast), and 37 % (316 colonies) at Nishihama (eastern coast). At all localities, except Nishihama, both coral coverage and number of colonies per unit area have decreased. At Nishihama, the number of colonies decreased over the next year but coral coverage increased. In 2000, both coverage and the number of colonies decreased in Maenohama, but were almost unchanged in Kushibaru and Sakubaru. Both coral coverage and colony abundance increased in Nishihama. In 2001, the state of the reef was as follows: 30 % (292 colonies) in Kushibaru, 31 % (450 colonies) in Sakubaru, 26 % (106 colonies) in Maenohama, and 53 % (324 colonies) in Nishihama. A survey in December 2003, found a decline in coral cover at all four localities – a consequence of *A. planci* predation (Taniguchi 2004).

Photo. 3. Humpback whales (*Megaptera novaeangliae*) are commonly seen in January to April in Kerama Islands, as their breeding ground.

2. Bleaching

In 1998 coral bleaching occurred on a worldwide scale. Bleached corals were first observed in the Kerama Islands at the end of July. By the end of August, *Seriatopora hystrix*, *Pocillopora damicornis*, and *Acropora* colonies were bleached at shallow area (< 3 m), as was *Acropora horrida* at 25 m. The result of September 1998 survey, at 15 localities, showed more than 90 % of the shallow colonies examined were bleached at 4 of 15 localities (in the inner bays or moats) (Taniguchi *et al.* 1999).

The belt transect results showed that 33 % of all the colonies examined were completely bleached, in September 1998 at Maenohama, and if partially bleached colonies were included, then 91 % of the colonies were bleached. By March 1999, only 64 % of the colonies remained (191 of 298 colonies surveyed). By November 1999, only 42 % remained), but the overpass of a typhoon was primarily responsible for the latter lose (Taniguchi and Iwao 2000). There were signs of recovery, based on re-growth from remnants and newly recruitment, but thermal stress and bleaching was again evident by the end of July 2001. In 1998, about 25 % of the corals died in Maenohama, which experienced the greatest lose, while mortality in 2001 was only 10 % (Taniguchi 2002).

3. Crown-of-thorns starfish

A well documented outbreak of *A. planci* in the 1970s changed the coral reefs of Okinawa considerably. A similar outbreak occurred on Chibishi reefs in 1997, between Okinawa and the Kerama Islands. In autumn 2001 an *A. planci* outbreak occurred on the Kerama Islands. Extermination was undertaken especially in the conservation areas; at three localities in the Zamami district (Nishihama on Akajima, southeast of Amuro Island, and on the south coast of Gahi Island), at two localities in the Tokashiki district (Arigah on Tokashiki Island and off Aharen Bay on Tokashiki Island). Local diving operators exterminated the starfish and these activities are continuing – some 120,000 *A. planci* individuals were exterminated in the last 2 years (to June 2003).

4 Monitoring

1. Belt transect survey

Monitoring was conducted by the Akajima Marine Science Laboratory (AMSL) at each of the four survey localities. At each locality a 30 × 0.5 m belt transect recorded coral communities. These surveys are repeated annually to determine the change in coral coverage, the number of coral colonies, and growth and death of each coral colony.

Photo. 4. Reef Check monitoring by volunteer divers in Kerama Islands.

2. Reef Check

At Zamami village, since 1998, local divers have followed 'Reef Check' protocol as part of the coral reef conservation efforts (Photo. 4). Since 1999, the year after Nishihama was closed, Reef Check surveys have been conducted. In 1999, coral coverage at Nishihama was 29 %, which appeared to increase to 41 % in 2000, and 48 % in 2001. Moreover, the number of fish and invertebrates have also increased.

3. Other surveys

In addition to the above-mentioned surveys, AMSL has been observing weather and oceanographic conditions, such as temperature, seawater temperature, and precipitation, every day since 1988. Moreover, plankton samples have been collected once a month off the southern coast of Akajima since 1989.

5 Conservation and research

1. Conservation activities

Considering reports of deterioration of coral reefs at several diving localities, Zamami Village Fishery Cooperative closed three diving sites for three and a half years, in July 1998. Mooring buoys were installed when the sites re-opened at Nishihama to prevent anchor damage and limit the number of boats to the area at any one time.

All the diving businesses on Akajima and Geruma Island in Zamami village participated in organizing the 'Aka & Geruma Diving Association' in November 2001, and coral reef conservation activities have been proactively implemented. For instance, the society led the transplantation of coral colonies from the east coast of Geruma Island to Nishihama and Majanohama (Akajima), before the colonies were damaged by road construction in January 2002. Most recently, a 'Zamami Diving Association' has been established (Hosaka and Taniguchi 2003).

2. Akajima Marine Science Laboratory (AMSL)

AMSL was established in July 1988 on Akajima, surrounded with rich coral reefs. Since then, in cooperation with local residents and many researchers both domestic and international, the laboratory has been actively researching coral reproduction, recruitment and coral settlement processes, which is highly applicable to conservation issues. Moreover, AMSL continues with education and awareness activities that involve local schools and the local community, by operating summer school and preparing pamphlets and newsletters.

6 Necessary measures

Recently, many research reports have highlighted the Kerama Islands as the main source of coral larvae for Okinawa and surrounding islands. Therefore, preserving the reef around the Kerama Islands is a regional issue. Although heavily damaged by an *A. planci* outbreak over the past two years, and showing some resilience to the 1998 and 2001 bleaching events, the reefs are still rich in biodiversity and aesthetically appealing. There is a general consensus in the Kerama Islands that human disturbances need to be kept low. There are no large rivers, and little pollution in the Kerama Islands. The fishery cooperative and diving association are now actively engaged in coral reef conservation, which gives hope for the Kerama Islands of the future.

c. Iheya, Izena, Aguni, Tonaki, and Kume Islands

(Maps 6-1-4-③～⑥)

Kazuyuki Shimoike

1 Corals and coral reefs

1. Geographical features

Iheya, Izena, Aguni, Tonaki, and Kume (ordered from north to south) are islands scattered between Okinawa Island and the Okinawa Trough (basin). The Okinawa Trough connects to the Kerama gap, south of Kume.

Iheya and Izena are located about 30 km north of Motobu Peninsula, Okinawa, and their highest points above sea level are 293.9 m and 119.9 m, respectively (Photo. 1). These hilly areas consist of alternating strata of chalk, sandstone, and shale (Kizaki 1985). On Iheya, two mountains run parallel to the long axis, and dunes of up to about 80 m above sea level develop at the northern tip (Mezaki 1988). On Izena, the hilly regions are located in the central and northeastern parts of the island, and strata of chalk can be observed (Mezaki 1988). These mountains are designated Nature Conservation Areas in Okinawa Prefecture.

Aguni (about 4 km east-west by 3 km south-north) is located approximately 60 km northwest of the city of Naha on Okinawa. To the west of this island, steep dropoffs of 1,500 m or more have developed, running north-northeast to south-southwest at the sea floor (Kizaki 1985). The island mainly consists of a terraced structure made of limestone, and the highest point is 97.3 m in the southeast, where the southeastern tip is fringed with abraded cliffs about 80 m high. Beach rock and dunes are well developed along the east coast.

Approximately 50 km west-northwest of Naha is the island of Tonaki (about 2.5 km east-west by 4 km south-north). Its highest point is Mount Otake (179 m). The foundation of the island is limestone, dolomite, phyllite, and volcanic rock of the Tertiary Cenozoic era (Kizaki 1985). The low ground at the center of the island is formed of tronbo structures (islands that are joined with the cay; Kan *et al.* 1997). A conglomerate of beach rock and Holocene coral reefs protected by the beach rock is distributed on the shores (Kawana 1996).

The island of Kume is located about 90 km west of Naha; its highest point reaches 326 m above sea level. The foundation of this island consists of Pretertiary layers and volcanic rock of the Tertiary Period (Kizaki 1985). A beach (Hatenohama) of Holocene coral reef deposits and sand-gravel extends nearly 8 km along the east coast (Machida 2001).

2. Coral distribution

According to the 4th National Survey on The Natural Environment (Nature Conservation Bureau, Environment Agency 1994), coral communities are well developed in this area as compared to those in the region around Okinawa. However, Aguni was not included as a targeted survey site. Of the 272.5 ha covered by coral on Iheya, areas with coverage of 50 % or more accounted for 68.3

Photo. 1. Aerial photograph of Iheya and Izena (September 2003). At left is Iheya Island, on the right is Izena Island; the island in the center is Gushikawa Island. These islands are surrounded by well-developed fringing reefs. Okinawa Island can be seen in the background.

% of the total while areas with coverage of 5 % or less accounted for only 14.2 %. High coverage by *Acropora* and *Montipora* communities could be seen throughout the fringe of the island. Hermatypic corals (hereafter, corals) were also abundant along the reef crest, on which areas with coverage of 50 % or more accounted for 45.7 % of the total length surveyed (39.2 km).

While branching *Montipora* were dominant (50 % or more) in the moat, tabulate *Acropora* were dominant (50 % or more) on the reef crest along the southeast coast of Izena. Of the 105 ha area covered by coral on Tonaki, areas with 5–50 % coverage accounted for 71.4 % of the total area, and areas with coverage of 50 % or more accounted for 28.6 %. Coral communities dominated by branching *Porites* and *Montipora* were distributed in the moat. On Kume, however, frequently exposed reef flats are widely distributed, and the moat is seldom visible. Branching *Montipora*-dominated communities (50 % or more) extend for 41 ha around Oojima, located on the east coast. The results of a survey conducted by Narure Conservation Division, Okinawa Prefecture (1999) revealed that large tabulate *Acropora* covered the patch reefs off Hatenohama and that the coral fauna (dominated by branching *Acropora formosa* and large colonies of *Favia*, *Pocillopora*, *Merulina ampliata*, and *Diploastrea heliopora*) was in good condition on the reef slopes.

According to a survey conducted by the Nature Conservation Bureau, Environment Agency (1994), the coral fauna was relatively impoverished, i.e., had low coverage, on Gushikawa, which lies between Iheya and Izena. However, a survey conducted in 2001 (Irikawa 2002) reported tabulate and branching *Acropora* communities with 64 % and 92 % coverage at depths of 2–3 m and 9–10 m, respectively, along the northern coast of the island.

3. Water quality and physical environment

The Kuroshio Current flows from southwest to northeast along the Okinawa Trough on the northwestern side of these islands, making water temperatures and clarity high throughout the year. However, inflow of terrestrial red clay is evident in some coastal areas of the islands.

4. Notable species and ecosystems

The fringing reefs of Tonaki have been designated as one of the 500 Important Wetlands of Japan (Nature Conservation Bureau, Ministry of the Environment 2002a). Mangrove trees, such as *Bruguiera gymnorrhiza* and *Kandelia obovata* (see Chapter 1-3), are distributed at the mouth of the Gima River in Kume Island and provide habitat for birds such as *Anas poecilorhyncha*, various ardeids, and *Phalacrocorax filamentosus* (Nature Conservation Division, Okinawa Prefecture 1999).

2 Situation of usages

1. Tourism

Leisure fishing is very active throughout these islands. A national fishing rally is held annually in June on Kume. SCUBA diving is also popular, and there are 14 dive shops on Kume. The coastal areas are also often used for camping and swimming. The natural stone pavement called 'Tatamiishi', with large pentangular and sextangular shaped rocks that resemble tortoise shell, has been designated a Prefectural Natural Treasure and is a popular tourist spot.

2. Fishery

The most commonly caught fish around these islands are tuna offshore, *Sthenoteuthis oulaniensis* by coastal fisheries, and snapper and grouper by towing net fisheries, pole and line fisheries, and gill net fisheries; shellfishes and seaweeds are also harvested from the surrounding sea. The cultivation of the brown algae (*Tinocladia crassa*) is common on Iheya and Izena, and the prawn (*Penaeus japonicus*) is raised on Kume.

3. Deep-sea waters

Taking advantage of its geographical location close to the Okinawa Trough, Kume has developed a new industry, which uses deep-sea waters pumped up from a depth of 600 m or more. These deep-sea waters are virtually aseptic and replete with nutrient salts; thus, they can be used in the manufacture of health foods and cosmetics, capitalizing on the recent boom in this field.

3 Monitoring and conservation

1. Sedimentation

As a result of the enforcement of the Okinawa Prefecture Red Soil Erosion Prevention Ordinance of 1995, red soil run-off has been controlled. The rate at which run-off increases the suspended particles in sea sediment (SPSS; see also Chapter 2-5) in coastal areas of Kume has

decreased somewhat, although run-off still occurs at a relatively high rate. Moreover, the rate of SPSS in Iheya and Izena is increasing even after the enforcement of the ordinance (website of the Okinawa Prefectural Institute of Health and Environment *1). Many sugarcane fields on these islands do not comply with the ordinance; this is considered a major obstacle to improvement and thus requires countermeasures.

2. Bleaching

The results of a questionnaire intended for city, town, and village officials showed that the ratio of bleached to live coral exceeded 60 % on Iheya, Izena, and Kume. The ratios of corals that died after bleaching were 20–80 % in Hatenohama and 80 % throughout Kume (Nature Conservation Bureau, Environment Agency 2000c). Bleaching occurred again in 2001, and *Acropora* communities on Gushikawa (located between Iheya and Izena) and *Porites* and *Montipora* communities on Kume, which survived the bleaching event in 1998, have since died out (Photo. 2). However, 50 % or greater of the communities survived the bleaching event in some areas, including the mixed species communities in the northern part of Ie as well as tabulate and branching *Acropora*-dominated communities in northern Gushikawa (Irikawa 2002). These survivors are expected to play an important role as sources of larvae for the neighboring coral reefs, including the west coast of Okinawa.

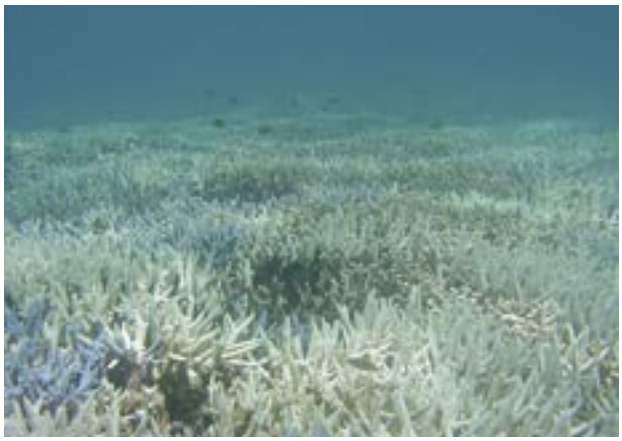


Photo. 2. Coral community on southern Iheya Island (1 August 2001, 3 m depth). (photo by A. Irikawa)
This community was once dominated by *Acropora* (e.g., *Acropora formosa*, *A. nobilis*, *A. microphthalma*, and *A. valenciennesi*), but many corals died after the bleaching event in 2001.

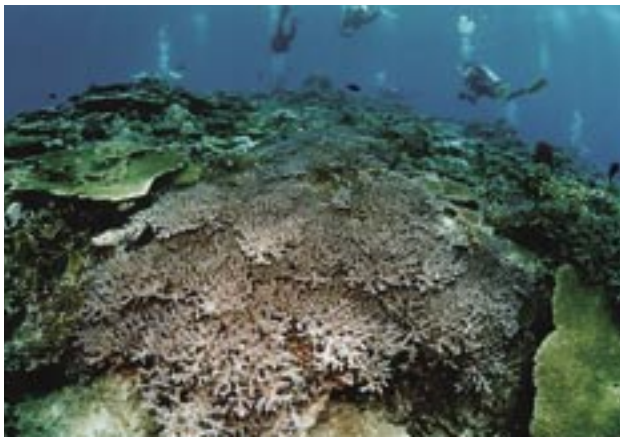


Photo. 3. Seascape of Akashita, Kume Island (June 1998, 3 m depth). (photo by N. Watanabe)

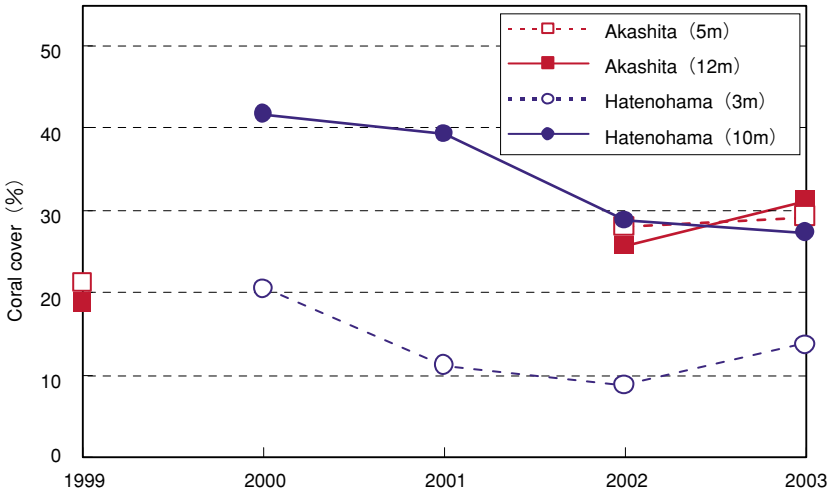


Fig. 1. Transition of hermatypic coral cover in Kume Island from the Reef Check monitoring.

3. Reef Check

Reef Check, an international standardized method of monitoring by volunteer divers (see also Column: 'Reef Check in Japan'), has been conducted on Kume since 1999. The result of the Reef Check monitoring survey is shown in Fig. 1. The state of coral communities at both surveyed sites (Akashita, on the north shore of Kume (Photo. 3), and Hatenohama) remains good at present. But, outbreak is worried because two crown-of-thorns starfishes (*Acanthaster planci*) were found on Akashita in 2003. (website of Reef Check Japan *2).

4. Zoning

Okinawa Prefecture has formulated an indicator system to evaluate the conservation needs of natural environments. As part of this process, the coastal areas of Kume have been classified into four priority rankings according to their conservation requirements (Nature Conservation Division, Okinawa Prefecture 1999). This act aims to advance the protection and conservation of natural areas, based on the indicator system.

4 Necessary measures

Little research has been conducted on these islands since the 4th National Survey of the Natural Environment (Nature Conservation Bureau, Environment Agency 1994), with the exception of a few sites. Thus, even the status of *A. planci* is currently unknown. However, a trend toward increasing numbers of *A. planci* was observed in Gushikawa from 2003 to 2004 (Irikawa personal communication); therefore, immediate measures, including monitoring surveys for coral reef conservation, are required to determine the current status of *A. planci*.

Cited websites:

*1: http://www.c-okinawa.co.jp/eikanken/akatuti/umi/umi.htm

*2: http://hs.st41.arena.ne.jp/reefcheckjapan/