Mitsubishi Corporation

Corporate Citizenship Report

Global Coral Reef Conservation Project

For a sustainable future

Mitsubishi Corporation's Global Coral Reef Conservation Project

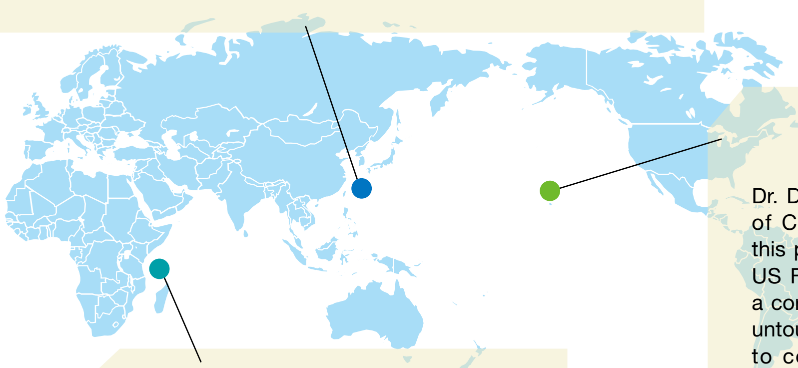
Contributing to the Conservation and Rejuvenation of Coral Reefs

The Challenge: Conserving Coral Reefs Around the World

The Global Coral Reef Conservation Project conducts surveys and research into ways to protect coral reefs from various different approaches. The Project focuses on three locations around the world: Okinawa, Midway, and the Seychelles. Research in Okinawa began in fiscal 2005, followed by the Marine Protected Area of the United States' Midway Atoll and the Republic of the Seychelles in fiscal 2006. Groups of volunteers recruited from both inside and outside the company support these research activities.

Okinawa

Professor Yoshimi Suzuki of Shizuoka University leads this project, a partnership between Shizuoka University, University of the Ryukyus, and international environmental NGO Earthwatch Japan. The aim of the research is to uncover the causes and mechanisms of the coral bleaching phenomenon, to conserve reef health, and to eventually establish and disseminate scientific recovery methods.



Midway

Dr. Donald Potts of the University of California, Santa Cruz leads this project, with support from the US Fish and Wildlife Services, at a coral reef that has been virtually untouched by past human activity to comprehensively study how coral is impacted by global and local climate change.

Seychelles

Dr. David Smith of the University of Essex in the UK leads a partnership between MC, the University of Essex, and Earthwatch Europe, collecting data on the biodiversity and health of the coral reefs and mangroves in the Indian Ocean archipelago of the Seychelles.

The aim of the Global Coral Reef Conservation Project is to conduct scientific research on the current state of coral reefs in order to contribute to the establishment of future conservation methods and technologies to help rejuvenate reefs around the world. So that the results can be implemented globally, part of the Project includes holding academic conferences and seminars.

MC believes that establishing technologies to preserve and help restore coral reefs will play an important role in maintaining the rich biodiversity of marine environments as a whole.

The Role of Coral Reefs in Protecting the Marine Environment

Coral reefs provide a home for living creatures, thereby playing an important role in preserving the marine environment. But reefs also have a deep connection with the day-to-day lives of human beings. According to estimates by the United Nations Environment Programme (UNEP),* the annual economic value provided by coral reefs is equivalent to between US$100,000 and US$600,000 (¥10 million — ¥60 million) per square meter.

* UNEP report *In the front line*, released January 2006.

Biodiversity

Coral reefs have been called "the rainforests of the sea." It is estimated that one-quarter of the roughly 500,000 marine animal species lives in coral reefs, making them a treasure trove of biodiversity. Coral reefs have high biological productivity, meaning they are a base for the creation of rich marine ecosystems.

A Tourism Resource

Home to so many different species of marine life, coral reefs offer a visually impressive and enjoyable experience for visiting scuba divers and snorkelers.

An Underwater Classroom and Laboratory

With their abundance of living creatures, coral reefs are an ideal "laboratory" for education and research. They can be used as part of environmental education programs through natural observation groups and clean-up activities.

Nature's Breakwaters

During typhoons and other storms, coral reefs serve as a breakwater, protecting the people and animals that live on islands by lessening the impact of waves from the open sea. They also help limit the damage caused by tsunamis.

Fishery Resources

Many types of fish and shellfish live in coral reefs. For generations, local people have used the sea's bounty as an important source of food.

Coral is an animal with both a mouth and stomach.

Coral Reefs: The Rainforests of the Sea

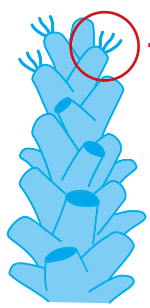
Coral reefs are home to various living creatures, and coral thus helps to provide a vital marine ecosystem. But what exactly is coral? Learning the basics is the first step toward conserving coral reefs.

Coral: An Animal With both a Mouth and Stomach Among Other Features

Corals have branches like a tree and more or less resemble a plant since, at first glance, they do not appear to move at all. Upon closer inspection however, corals, are in fact a member of an animal phylum called Cnidaria, which makes them relatives of sea anemones and jellyfish.

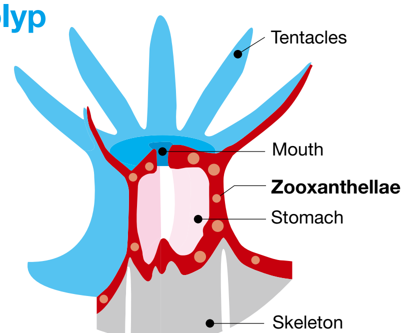
Coral is actually formed by many tiny individual bodies clustering into groups. A single coral, as shown in the illustration below, is made up of bodies called polyps that have a mouth, tentacles, digestive system, and a calcareous skeleton. Around the mouth are arm-like structures called tentacles, which capture plankton and transport it to the mouth. The mouth itself is used not only for eating, but also for expelling waste and releasing eggs for reproduction.

Colony view



Many corals live in "colonies" which are large collections of polyps.

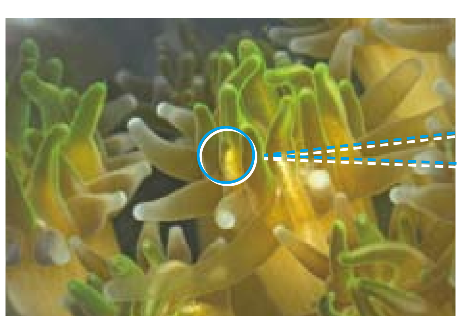
Polyp



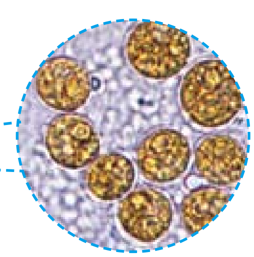
As shown in the illustration, corals have stomachs and mouths through which they feed and spawn, making them members of the phylum Cnidaria. Within corals live many algal plankton called zooxanthellae.

Coral's Symbiotic Partner: Zooxanthellae

Within corals live a large number of microscopic algal plankton called zooxanthellae that measure just 1/100 of a millimeter in diameter and perform active photosynthesis. Corals are not only a place for these algae to live; they also provide algae with nutrients required for photosynthesis (carbon dioxide, nitrate and ammonia). In return, corals receive the oxygen, carbohydrates, proteins and other organic materials produced during planktonic photosynthesis as energy of calcification.



Polyp



Zooxanthellae

(Zooxanthellae are too small to be seen by the naked eye.)

Coral and Coral Reefs

In order to assist zooxnathellae with photosynthesis, coral branches extend out like the branches of trees to get more sunlight, blocking other corals. They also grow in many shapes; they can be table shaped, branch shaped, or rock shaped. “Coral reef” is a term describing the formation built over a long period of time by layer upon layer of calcareous coral skeletons.


Branch shape

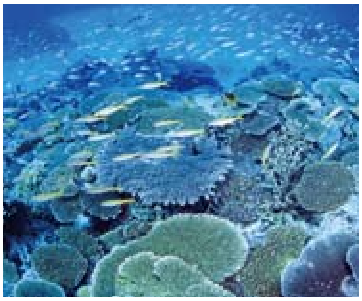


Table shape

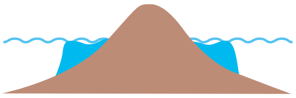

Rock shape

Three Types of Reef

There are three types of coral reefs: fringing reefs which are attached to the shore; barrier reefs which are separated from the shore by a shallow lagoon; and ring-shaped reefs called atolls.

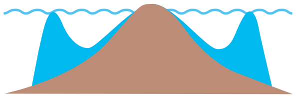
Charles Darwin, author of the book *The Origin of Species*, which laid the groundwork for evolutionary theory, was the first to explain how these three types of reef form as islands settle and sink in the ocean, as described below.

Fringing reef



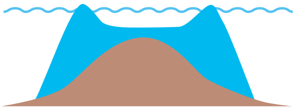
A fringing reef is a formation whereby a reef is attached directly to the shore. When land is created by undersea volcanic eruptions or tectonic movement in marine environments suited to coral growth, corals will grow in the shallows surrounding the land. As it continues to grow, the coral extends outwards around the island like a fringe.

Barrier reef



In a barrier reef formation, the reef is separated from the shore by a shallow area of sea (lagoon) 10-80 meters in depth. Fringing reefs exposed to the outer sea can develop into barrier reefs if the movement of the earth’s crust or a rise in sea level cause the island or mainland to sink below sea level.

Atoll



An atoll is a formation in which an island becomes completely submerged and all that remains is the coral reef in the shape of a ring, and small islands form as sand accumulates above the reef. Many atolls can be found in the Maldives and the Marshall Islands.

Corals reproduce by releasing eggs

Environments Suitable for Coral Growth

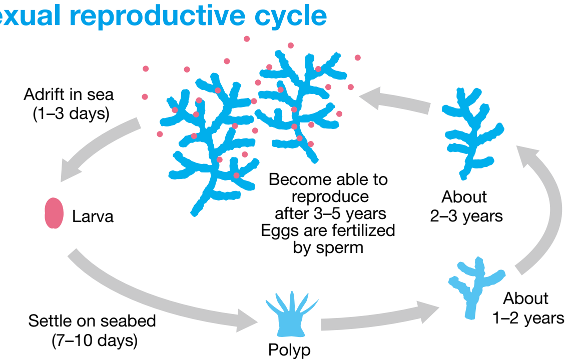
Coral Spawning and Growth

Corals have a mass annual spawning. The timing of the breeding season and actual spawning date vary by region and type of coral. The Acropora coral species most commonly seen in Okinawa generally spawn in June around the time of the full moon.

Coral reproduction can be sexual or asexual. In sexual reproduction, the polyps release eggs and sperm into the open water, where they meet and the sperm fertilize the eggs. The larvae then settle elsewhere and start to grow. Asexual reproduction involves the division of polyps to create fragments that regenerate.

In many coral species, sexual reproduction involves the fertilization of eggs in the water to create larvae. These float in the sea for a short time before eventually settling on the seabed. Once fixed, the larva forms a new skeleton, developing into a polyp. The polyps then divide and multiply, forming a new colony.

Sexual reproductive cycle



Coral spawning

Sea Habitats for Coral

Corals are best adapted to warm seas with an ambient temperature range of 18–30°C. For this reason, coral reefs are mostly found in the warm seas of the tropics and subtropics around the equator, in latitudes between 30°N and 30°S. The areas with the world's greatest coral biodiversity are the seas around Indonesia, the Philippines and Papua New Guinea, where more than 450 species of coral live.

Growth of coral reefs requires a minimum water temperature of around 18°C. Japan is therefore at the northern edge of the coral and coral reef distribution area.

Reef-building corals grow at depths of up to 20 meters, because the zooxanthellae that live inside the coral require sunlight for photosynthesis. In tropical seas with strong sunlight, corals can be seen at depths of up to 80 meters.

Issues Facing Coral Reefs

The Coral Bleaching Phenomenon

Coral consists of calcium carbonate skeletons and polyps made of organic material. Because of this, coral is white by nature; the browns, purples and greens that appear to color them are actually produced by the symbiotic algal plankton called zooxanthellae that live inside coral. In recent years, the “bleaching phenomenon” has become an issue with coral. The theory is that as a result of rising sea temperatures or other forms of stress, zooxanthellae are dying or leaving corals, causing corals to lose color.

When corals cannot receive sufficient nutrients from zooxanthella, they gradually weaken and eventually die.

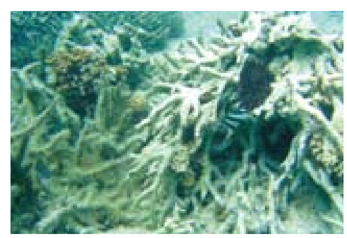
In recent years, the greatest damage to corals has been bleaching as a result of rising water temperatures associated with the El Nino phenomenon* in 1998 which affected coral reefs around the world.

*The El Nino phenomenon refers to a period of approximately one and a half years marked by above-average annual ocean surface temperatures across a wide area, extending from the equatorial regions of the Pacific around the International Date Line to the coast of Peru in South America.

Areas around the world affected by coral bleaching as of 1998

● Serious bleaching ● Bleaching identified ■ Main coral colonies ■ Perimeter of coral colonies

Source: Japan National Institute for Environmental Studies Center for Global Environmental Research (Data Book of Sea-Level Rise 2000)



Bleached coral

Damage From Development and Sand and Soil Runoff

When plants no longer grow in a given area due to deforestation, civil engineering in river deltas, and conversion of deltas to agricultural land, rain can wash large volumes of soil into rivers, which eventually reaches the sea. When a large amount of sand is deposited on coral, the coral cannot remove the sand by itself and is unable to feed or breathe, in some cases leading to death.

Moreover, when the ocean is polluted with soil, sunlight can no longer reach coral, impairing the ability of zooxanthellae to photosynthesize, adversely affecting the coral. In Okinawa, this has been termed “red soil pollution” because of the color of the soil in the waters. Runoff of sewage and agricultural chemicals are also dirtying seas and oceans.

Red soil pollution

Global Coral Reef Conservation Project

Okinawa

Okinawa

■ Special Regional Characteristics

Over 360 different types of coral, varying in color, shape and size, are believed to live in Okinawa. The Okinawa project is based on Sesoko Island, off the Northern Coast of Okinawa's main island in the East China Sea. There, the team conducts research to help conserve coral.

■ Purpose of Project

Research into the causes and mechanisms of coral bleaching and establishment and propagation of reef conservation and bleaching recovery technologies.

■ Research Framework

- Professsor Yoshimi Suzuki of Shizuoka University Graduate School of Science and Technology leads the project, working with research scientists and students from Shizuoka University, University of the Ryukyus, Kokushikan University, and other educational and research institutions.
- Research activities are based out of the Tropical Biosphere Research Center University of the Ryukyus (Motobu, Kunigani-gun, Okinawa Prefecture).
- Research is being carried out in cooperation with international environmental NGO Earthwatch Japan from 2005 to 2010. Volunteers, including MC employees, provide basic assistance to the research surveys.

Message From the Project Leader

Our findings are changing conventional wisdom on coral bleaching

The goal of the project is to uncover the causes of coral bleaching scientifically so that we can eventually employ the natural regeneration and adaptation methods of coral reef organisms to restore coral and coral reefs. Our project team is conducting research to help make this goal a reality. The project has two unique features. First is our belief that the factors causing the bleaching phenomenon and the path to coral regeneration are internal to the coral and the surrounding reef micro-ecosystem. Second, our research is the product of cooperation between private citizens and companies as well as researchers. Our project findings are gradually changing conventional theories of coral bleaching.

Professor
Yoshimi Suzuki
Shizuoka University
Graduate School of
Science and Technology

New Findings on the Causes of Coral Bleaching

New Findings on the Causes of Coral Bleaching
Overview of Project Activities and Research

1. Survey of coral health and distribution around the research site
2. Do rising sea temperatures cause zooxanthellae to be expelled from coral? Questioning established theory
3. What happens to zooxanthellae inside coral?
4. What happens to coral in high-temperature water?
5. What impact does bacteria have on coral?
6. How does coral bleaching occur? What is the relationship with bacteria?
7. What happens to coral after bleaching has occurred?
8. Clarifying the reasons behind coral bleaching: a major project achievement

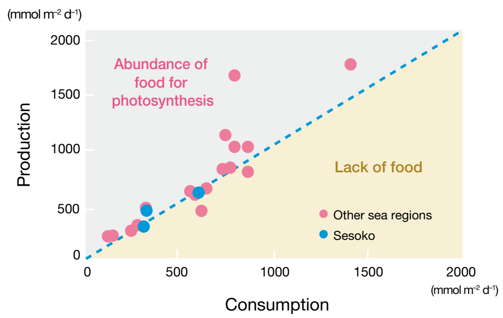
1. Survey of coral health and distribution around the research site

Determining the causes of coral bleaching requires surveys of coral and coral reefs to assess their health status. Comparisons of the corals at Sesoko with coral reefs in seas across the world show that Sesoko corals grow relatively quickly. This indicates that there is a good, productive balance between the various animals producing and consuming food in the coral reefs at Sesoko, creating a healthy reef environment. However, coral coverage* has decreased even at Sesoko over the past several years.

*The coral's seafloor coverage

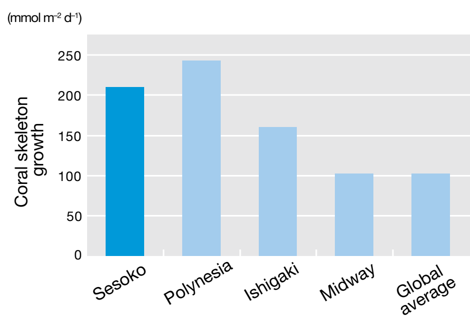
Amount of organic matter (food)

An important indicator for gauging the health of coral reefs is the balance between organic matter produced and consumed. The vertical axis shows the amount of food matter produced and the horizontal axis the amount consumed. The dotted 45° line shows the precise balancing point between these two amounts. Sesoko (shown in blue) is a well-balanced environment according to this measure.



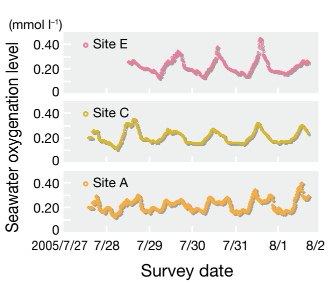
Growth of coral skeletons

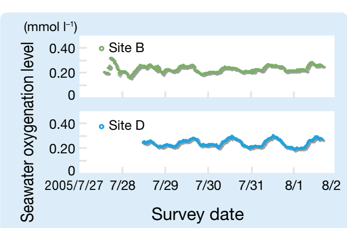
The graph shows skeleton growth rates for corals in the world's main coral regions. Sesoko's coral exhibits fast rates of growth compared with other parts of the world.

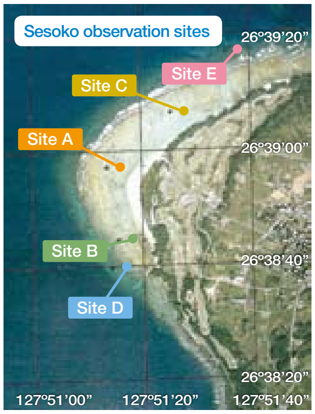


Dissolved oxygen in seawater

The level of oxygen in the seawater is a measure of coral production and respiration activities. Regular peaks and troughs indicate that a coral population is conducting photosynthesis normally, while a flatter graph indicates that the health of the corals is damaged to some extent. Production peaks when oxygen concentrations are high. During low oxygen periods, the corals consume the food produced earlier.





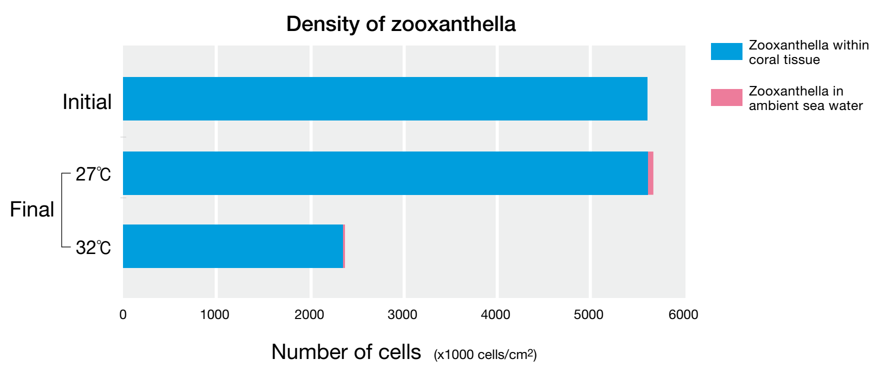


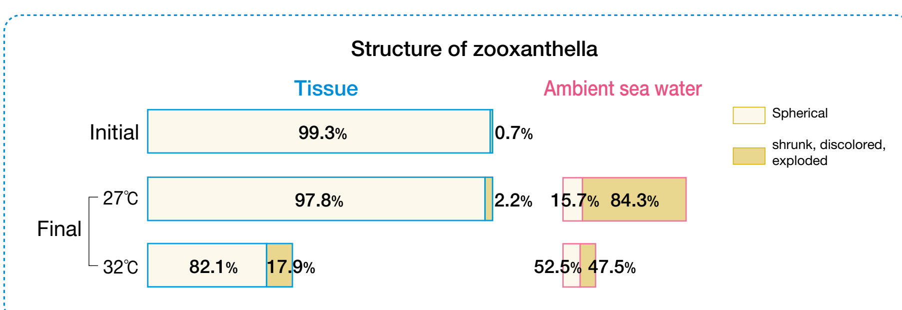
2. Do rising sea temperatures cause zooxanthellae to be expelled from coral? Questioning established theory

The theory to date has been that an increase in sea temperature causes coral bleaching by expelling the symbiotic zooxanthellae from the coral into the surrounding waters. The thinking is that loss of these algae, which provide corals with their attractive colors, turns the coral white and leads to the phenomenon of bleaching.

But are the zooxanthellae actually expelled from the coral? Quantifying the extent of this expulsion from the coral is no easy matter—in fact, since nobody has yet been able to produce data to answer this question, it is not well understood. An experiment conducted by the Global Coral Reef Conservation Project team confirmed that corals expel many more zooxanthellae at the optimal water temperature of 27 to 28℃ than at a high water temperature of 32℃ . However, the number of zooxanthellae expelled is tiny—no more than 1% of the total. In optimal water temperatures, more zooxanthellae that are deformed or have lost pigmentation are expelled. In high water temperatures, it was observed that the expulsion of these zooxanthellae is limited and they accumulate inside the corals. The experiment demonstrated that the expulsion of zooxanthellae from corals is a normal physiological activity of corals and thus has a low correlation to coral bleaching.

An experiment of response to thermal stress

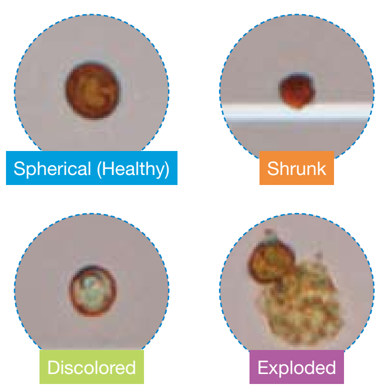




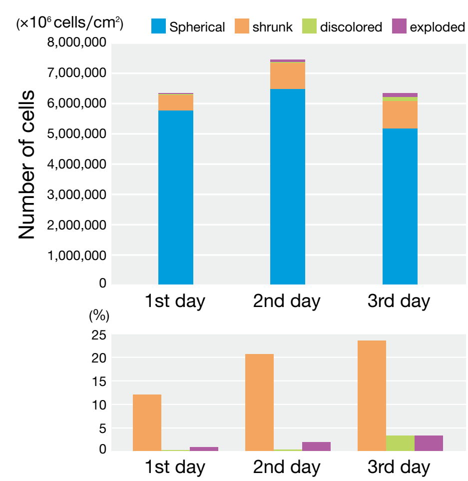
3. What happens to zooxanthellae inside coral?

Although the number of zooxanthellae expelled from coral in high-temperature water is minimal, the number of zooxanthellae living inside coral decreases sharply. This suggests it is highly unlikely that expulsion of these algae from the coral is the principal cause of coral bleaching. Rather, our research suggests that coral bleaching occurs because the zooxanthellae themselves disappear inside coral and that internal factors are at work. So what does happen to the zooxanthellae inside coral? The team investigated what happens to coral under thermal stress. We learned that the number of zooxanthellae cells inside living coral tissue decreased under thermal stress, and there was an increase in abnormal forms of zooxanthellae. This is the first time that a change in the form of zooxanthellae inside coral has been witnessed. We observed four forms of zooxanthellae inside coral: normal, shrunken, discolored and ruptured. The fact that there were still normal forms of zooxanthellae inside coral shows that the recovery from bleaching occurs inside coral. The cause of coral bleaching is the change of zooxanthellae to abnormal forms inside coral under thermal stress. The cause of these abnormal forms has a deep connection with bacteria.

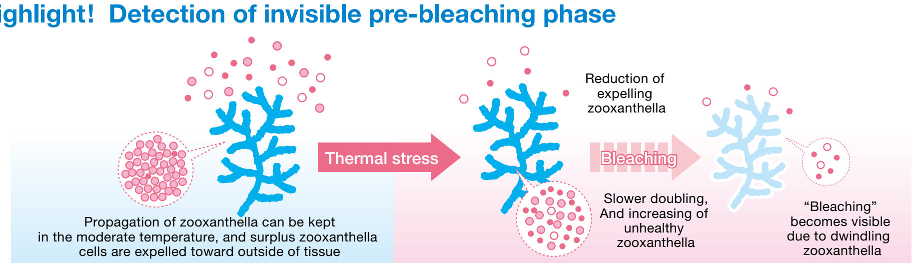
Cell strctures of Zooxanthella



Changes in morphology of zooxanthella within the coral tissue due to thermal stress



Highlight! Detection of invisible pre-bleaching phase



Research finding

Thermal stress causes deformities in zooxanthellae

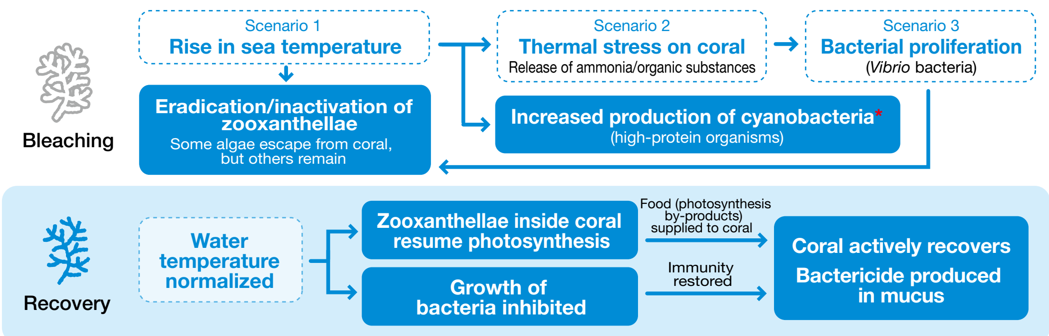
4. What happens to corals in high-temperature water?

Research showed that the main cause of coral bleaching is not the expulsion of these algae from the coral due to a rise in water temperature. So what does happen to the zooxanthellae? The cause is related also to the host coral. On the hypothesis that internal factors are at work, the team investigated what happens to coral under thermal stress.

Corals, like humans, experience thermal stress. In response to a rise in water temperature, corals release large amounts of mucus (mostly sugars and proteins) and ammonia. These substances provide excellent food for parasitic bacteria, which begin to breed rapidly. It is possible that this leads to an active invasion of the coral by such bacteria, damaging the zooxanthellae in the process.

Another theory under investigation is that bleaching is triggered by a decline in the photosynthetic ability of the zooxanthellae— a phenomenon that earlier experiments have demonstrated can occur.

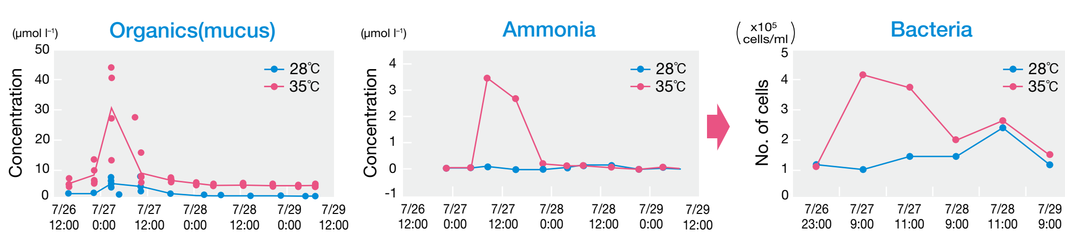
Three mechanisms for coral bleaching



*Also known as blue-green algae, cyanobacteria are photosynthetic prokaryotes that generate oxygen.

High-temperature coral stress and related microbial growth

This experiment tested the variation between the amounts of ammonia and organic substances (mucus) that corals released at 28℃, and when the water was heated to 35℃. Raising the temperature to 35℃ caused an increase in both mucus and ammonia, and also led to growth in the number of bacteria inside the coral.



Research finding

Large amounts of mucus and ammonia are released, leading to the rapid proliferation of bacteria

5. What impact does bacteria have on coral?

Surveys of bleached corals at the Sesoko site have confirmed the presence of many types of bacteria inside such corals. In addition to symbiotic bacteria that the corals have cultivated to boost their immunity, the team discovered strains of bacteria belonging to the Vibrio family and a new strain of *Paracoccus*. These bacteria may be causative factors in coral bleaching.

When *Paracoccus* bacteria is added to a coral breeding tank, the coral releases mucus in an attempt to protect itself from bacterial invasion. *Paracoccus* bacteria releases a specialized enzyme called a protease to break up the proteins in the mucus. It is possible that this enzyme inflicts damage on the zooxanthellae and coral, leading to coral bleaching.

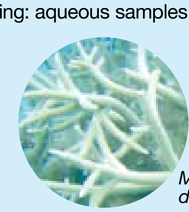
The team also learned that bacteria cause coral diseases such as white syndrome and black band disease. Scientific research of these coral diseases is an important theme in this project going forward, and the findings are much anticipated. This page shows some of the coral diseases. At present, most coral in Okinawa is affected by disease.

Co-culture experiments with coral and bacteria

These controlled experiments involve culturing coral in the presence of bacteria. Any bleaching observed points to the involvement of the bacteria in coral bleaching.

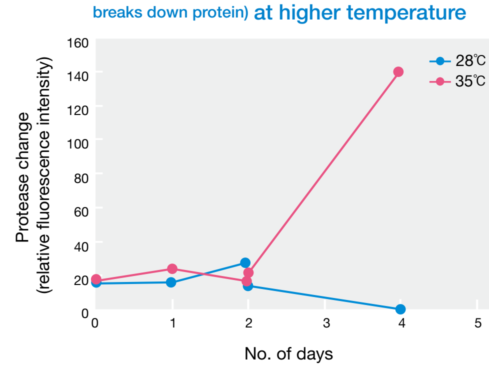
● Culture conditions

Coral: *Montipora digitata*
Bacteria: *Vibrio coralliilyticus, Vibrio harveyi, Paracoccus*
Incubation temperatures: 28℃ and 32℃
Sampling: aqueous samples taken daily at 4PM



Montipora digitata

Increased release of protease (enzyme that breaks down protein) **at higher temperature**

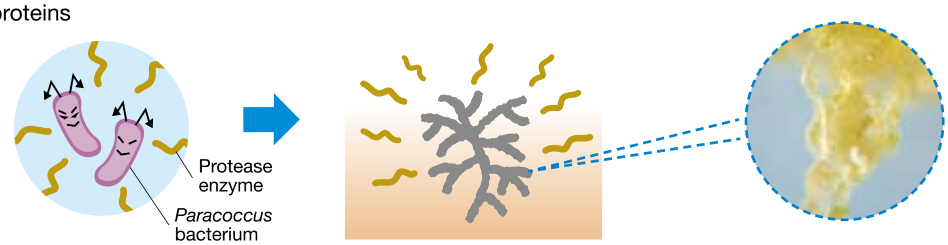


The coral-dissolving *Paracoccus* bacterium

①*Paracoccus* releases an enzyme that breaks up proteins

②Protease activity increases as water temperature rises

③Coral is bleached, skeleton partially dissolved



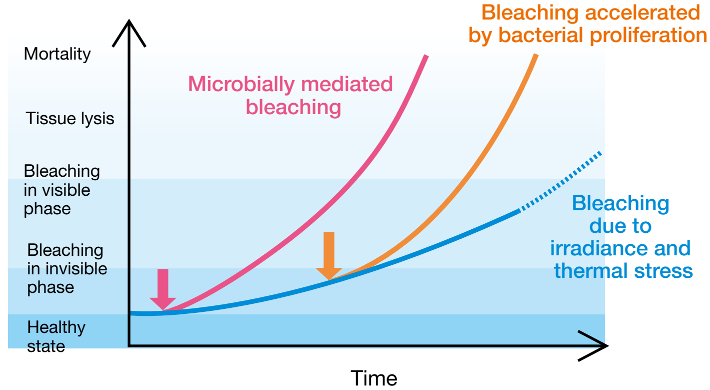
Research finding

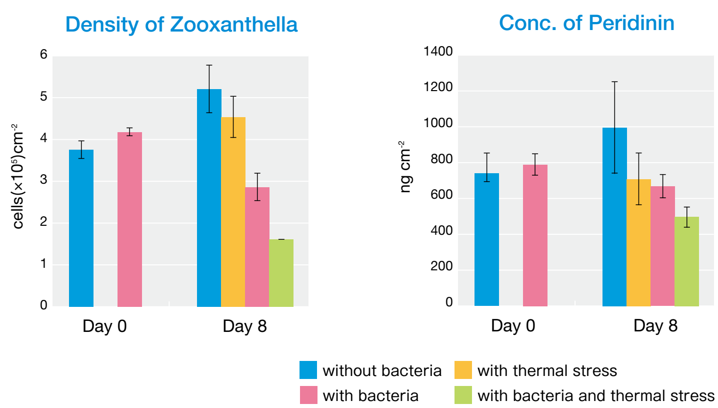
The project team found that *Paracoccus* bacteria can dissolve and bleach coral. Future research will study bacteria and fungi as the cause of coral disease

6. How does coral bleaching occur? What is the relationship with bacteria?

Research has found that the presence of specific bacteria in high-temperature water accelerates coral bleaching. While high water temperatures were previously identified as the cause for accelerating coral bleaching, this is the first time that research has focused on the relationship with bacteria as well. When bacteria infect zooxanthellae inside coral weakened as a result of high water temperatures, some zooxanthellae die or lose pigmentation. This combination of high water temperatures and presence of specific bacteria triggers the bleaching of coral. Eight days into observing coral bacteria in water temperatures between 28℃ and 32℃, bleaching was clearly evident. At the same time, some bleaching occurred in high-temperature water without bacteria, while in other cases no bleaching was observed in low-temperature waters despite bacteria being present.

Three possible ways of coral bleaching





Research finding

Research found that the presence of specific bacteria in high-temperature waters accelerates coral bleaching

7. What happens to coral after bleaching has occurred?

Previously, it was believed that coral would not recover until zooxanthellae returned from the seawater outside the coral, because there were almost no zooxanthellae left inside the bleached coral. However, while coral looks white in high-temperature waters, several tens of percent of zooxanthellae actually live healthily. When water temperatures drop and conditions enabling photosynthesis are met, a rapid recovery occurs.

Healthy corals typically consume nearly 80% of the organic matter produced by the zooxanthellae. The remaining 20% of this food is made up of cyanobacteria, microorganisms and plankton (both plant and animal). Once bleaching occurs the zooxanthellae stop supplying food, but this does not lead to the immediate death of the coral.

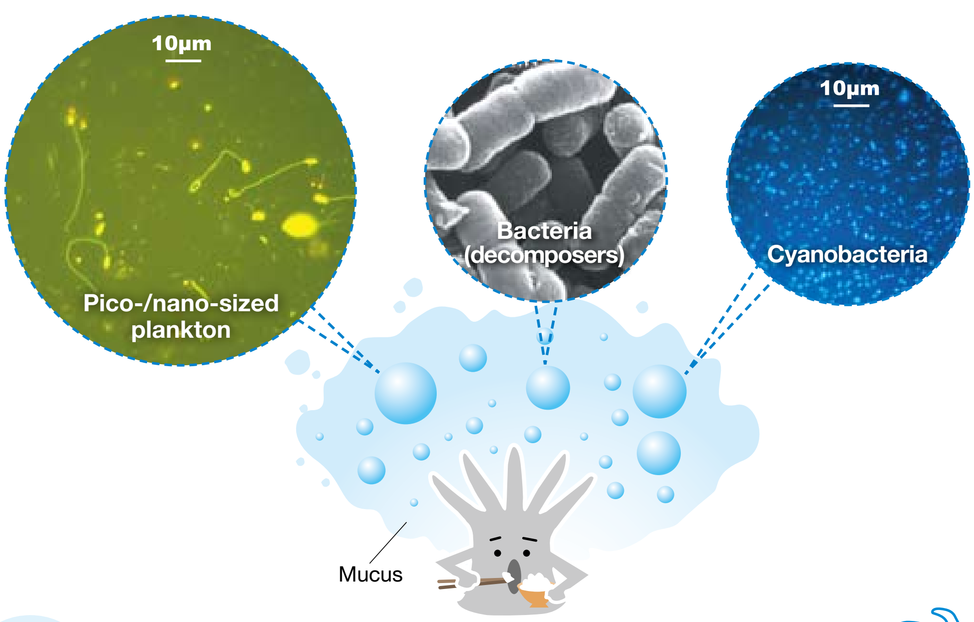
The team has studied what corals eat when the food supply from the zooxanthellae has stopped. Research shows that corals under these conditions consume bacteria (such as protein-rich varieties) and either pico-sized (under 2 micron*) or nano-sized (2–20 micron) plankton, which propagate even in high water temperatures. The composition of this food supply is roughly 50–60% cyanobacteria, 30% other microbes and 10% diatoms. The corals use the mucus that they excrete to bind this food before consuming it.

Coral tissue also has immunity created by an antimicrobial chemical compound which blocks or eradicates pathogenic bacteria. This antimicrobial activity is also being studied in this project.

*A micron/micrometer (μm) is one millionth of a meter (10^{-6} m)

Bleached corals

Corals can survive for some time after bleaching has occurred, by consuming plankton and bacteria as alternative sources of food.



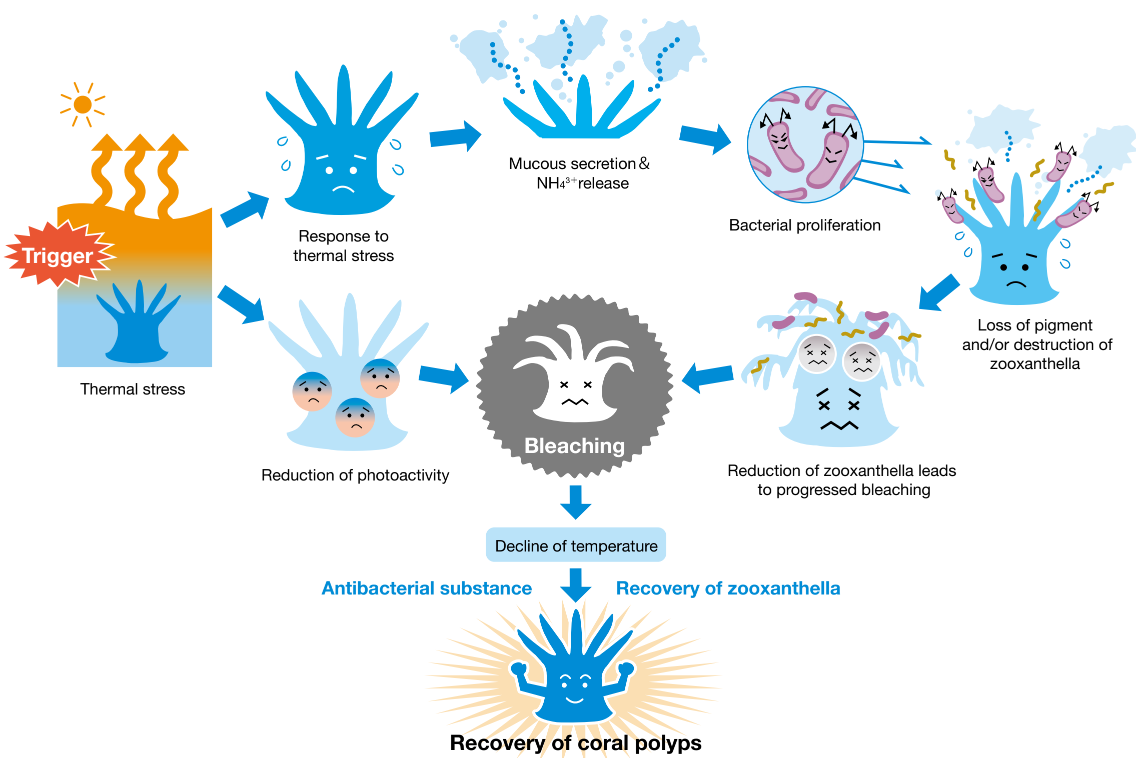
Research finding

Corals can survive even after bleaching

8. Clarifying the reasons behind coral bleaching: a major project achievement

Over the course of six years, the study has elucidated most of the causes of bleaching. Research has shown that coral and zooxanthellae experience stress in high-temperature waters. This stress causes a decline in the zooxanthellae's photosynthetic ability, which results in a decline in the number of cells because they cannot propagate. Meanwhile, stress also causes corals to produce large volumes of mucus and ammonia which was believed to protect them from high water temperatures. However, we have since discovered that it also leads to a rapid proliferation in bacteria that feed on the mucus and ammonia. The increased number of bacteria invade coral tissue, resulting in a loss of zooxanthellae pigmentation, cell deformation and death of zooxanthellae. In sum, a major cause of coral bleaching is the death of zooxanthellae, triggered by a build up of bacteria under high water temperature conditions.

Bleaching process discovered by GCRCP project



Summary

It is becoming clear from our research to date that external environmental factors can induce internal changes in the coral (such as disease and bleaching). The coral takes self-protective measures, releasing bactericides or proteins into the water. Ordinarily this organic matter would be expected to boost the immunity of the coral to aid future regeneration or else be directly effective as a regenerative substance. In the second stage of the project, we have already discovered several bactericides. It now appears that once the coral has been bleached, the mucus released to protect against other types of bacteria tends to diminish in both intensity and viscosity. The bacteria can then penetrate the thinned mucus and invade the coral, leading to pathogenic changes or bleaching.

The team's research achieved six specific goals: (1) identification of the microorganisms that cause bleaching by DNA analysis; (2) evaluation of the effects of proteases in terms of coral damage; (3) development of methods for observing, measuring and analyzing zooxanthallae, microorganisms, nutrient salts and organic substances inside coral; (4) confirmation that coral are self-sufficient with their own internal recycling system; (5) confirmation that coral reefs produce more organic substances than previously reported, which is why they are inhabited by diverse biological communities; and (6) confirmation that the reason coral reefs are an oasis for sea life is because they have much more nutrient salts than the surrounding seawater, which are present inside coral, sandy substratum, coral rubble and Cyanobacterial mat.

Research over six years in the micro and nano worlds of coral and coral reefs has produced a large number of new findings regarding coral bleaching mechanisms, as well as processes that maintain life on coral reefs.

■ Coral bleaching process elucidated by the research project

Sea temperature rises

▼

Coral and zooxanthellae experience stress

▼

Coral releases mucus and ammonia and the photosynthetic ability of zooxanthellae decreases

▼

***Paracoccus* bacteria and Vibrio bacteria multiply, invade coral, and release protease**

▼

Coral and zooxanthellae sustain damage, zooxanthellae lose pigmentation and die

▼

Sea temperature declines

▼

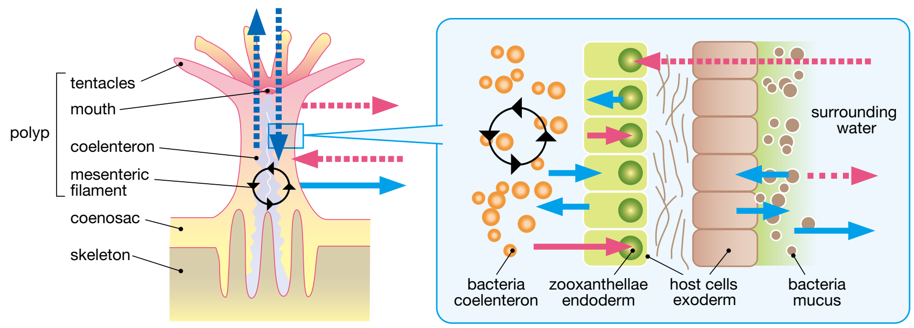
Surviving zooxanthellae resume photosynthesis

▼

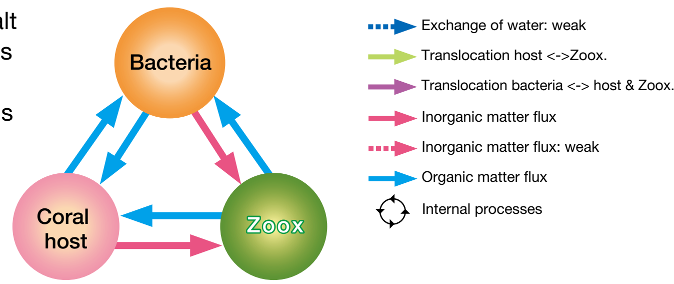
Coral produces bactericide

New Findings on the Causes of Coral Bleaching

Coral internal diagram



The self-sufficient nutrient salt and organic substance cycles inside coral are mainly the function of multiple symbiosis between zooxanthellae and bacteria.



Goals

Advancement of scientific knowledge

- Elucidate specific mechanisms of coral bleaching Search for scientific mechanisms of coral diseases, differences in bleaching and bacillus
- Establish conditions for ensuring healthy coral reef ecosystems and regeneration and recovery
- Develop ways of using natural engineering to regenerate coral and coral reefs

Development of research framework

- Establish model case for conserving coral reefs based on support from the general public, researchers and companies

Social and international significance of project

- As of the end of March 2011, the project had released announcements in both Japan (97 announcements) and the international community (46 announcements) and contributed to 11 scientific papers. Going forward, the project will generate more results using cutting-edge science to promote the international conservation of coral reefs, and to play a role in supporting international reef regeneration efforts and related research. In July 2012, 7 scientific papers are due to be presented at the 12th International Coral Reef Symposium to be held in Cairns, Australia.

Global Coral Reef Conservation Project

• Midway

Midway

■ Special Regional Characteristics

Midway Atoll is located over 2,000 kilometers from the nearest inhabited island (Hawaii's Kauai) and is one of the most isolated reefs in the world. Situated at the northern extreme of reef ranges, this reef is characterized by a low level of biological diversity and a high level of distinctiveness, with over half of the species endemic to the Hawaiian Islands. Furthermore the waters off the island are part of a marine wildlife reserve, where fishing has been almost completely banned for 70 years.

■ Purpose of Project

An integrated research program focusing on the consequences (physical, chemical and biological) of climate change on coral reefs, and their implications for how to best manage reefs.

■ Research Framework

Led by Dr Donald Potts, University of California, Santa Cruz, with active support and collaboration from UCSC graduate research students and from the US Fish and Wildlife Service.

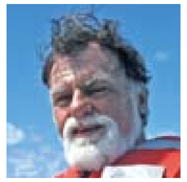
Message From the Project Leader

Our research into reef degradation will help to create a comprehensive coral reef management plan

We have learned that reefs on Midway Atoll are being eroded by natural processes, but this process is exacerbated by continuing effects of dredging and construction over the last 70 years. Other stresses include rising sea levels, ocean warming, ocean acidification, and debris such as fishing nets that drifts onto the reef. At this stage we cannot say whether the atoll will be able to survive the simultaneous impacts of all these environmental changes.

We have set up a program of physical, chemical and biological studies to determine the magnitudes of both growth and degradative processes.

In the future, our research findings at Midway will help in formulating a management plan for Midway Atoll.



Dr. Donald C. Potts
University of California, Santa Cruz

Studying the Relationship Between Marine Organisms and Reef Health

Review of Project History and Results

Prior to 2008, the project at Midway studied the degradation of coral reefs caused by erosion and sediments, as well as impacts of discarded fishing nets and metal debris. Project teams also observed the incidence of cyanobacteria around the reef.

In 2008, expanding on this earlier research, the team conducted further studies into the effects of cyanobacteria, sea urchins and fish on reef-building corals.

The team's research revealed that some sea urchins, usually thought to eat only algae, also consume living coral tissues and skeletons. Another research finding was that reef fish consume larger quantities of macroalgae (that may impede the growth of corals) than do sea urchins.

At the same time, areas of the reef where cyanobacterial blooms occurred had high rates of new coral recruitment, indicating that these blooms are not as detrimental as originally thought.

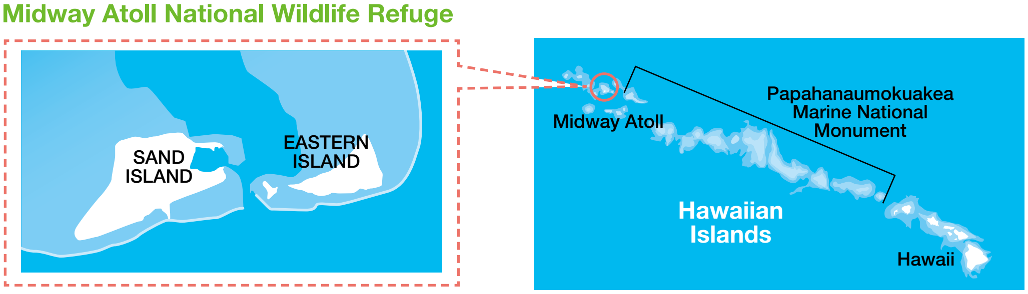
The most significant finding during 2008 was the discovery of a section of the Midway coral reef in apparently pristine (pre-human) condition. Surveys of this deepest part of the lagoon uncovered several rare species, including black-lipped pearl oysters (*Pinctada margaritifera*), finger corals (*Porites compressa*) and sea grasses.

Research at Midway

Midway Atoll is a high latitude (28.5˚N) reef, situated near the northern limit of reef ranges. Its location between cool and warm ocean currents makes it particularly vulnerable to both climatic and oceanographic change. Historically, the atoll has been subject to extensive engineering modifications as it was used as a military base for more than a century.

The aim of the research project at Midway Atoll is to conduct environmental studies of coral habitats and to explore ways of boosting the sustainability of these ecosystems.

■ Midway Atoll National Wildlife Refuge



Research program

The project's research at Midway focused on four main objectives:

1 Determining the relationship between cyanobacterial blooms and coral growth
2 Comparing the amounts of macroalgae consumed by fish and sea urchins
3 Exploring negative impacts of sea urchins on corals
4 Determining settlement rates and survival of the Black-lipped Pearl Oyster

Research Findings and Conclusions

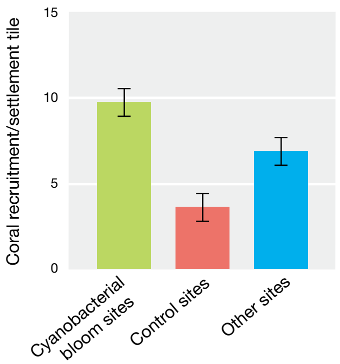
1. Cyanobacteria and coral recruitment

Part of the research at Midway has focused on effects of benthic cyanobacterial blooms. These bottom-dwelling blue-green algae grow on the surfaces of metal debris left behind from human use of the atoll. Some cyanobacterial species are known to both inhibit coral growth and be toxic to fish and humans.

As part of the project, the team studied the effects of these algae on coral recruitment by comparing two cyanobacterial bloom sites with control sites. The study found no evidence that blooms hinder coral recruitment; in fact, the sites with cyanobacterial blooms actually had higher rates of coral recruitment.

Coral recruitment data

Coral recruitment is highest at sites with cyanobacterial blooms.



2. Algal consumption by fish and sea urchins

Most sea urchins and some fish species are herbivores – that is, they eat marine plants (i.e. seaweeds, or algae). Algae compete with corals for space on the reef. In some coral habitats that have experienced heavy fishing, sea urchins can substitute for the lost fish by consuming macroalgae, creating enough open space for corals to settle and grow.

Midway is a very unusual reef in that it has not seen fish populations collapse due to over-fishing, because the atoll has been protected from fishing for many years, first as a US Navy base, and more recently as a National Wildlife Refuge. The reef is home to large populations of herbivorous fish and sea urchins that help to make Midway an ideal site for researching whether fish or sea urchins are more effective consumers of macroalgae.

To test this, the team created four environments containing: [1] grazing sea urchins and fish; [2] only fish grazing; [3] only sea urchin grazing; and [4] no grazing by either. They then measured the quantities of macroalgae surviving in each environment. Results showed that the greatest amounts of macroalgae were in the environments without fish ([3] and [4]), indicating that fish consume a greater biomass of algae than do sea urchins.

These results highlight the importance of herbivorous fish populations for coral growth, and support the need to maintain fishing restrictions and marine reserves in coral habitats.

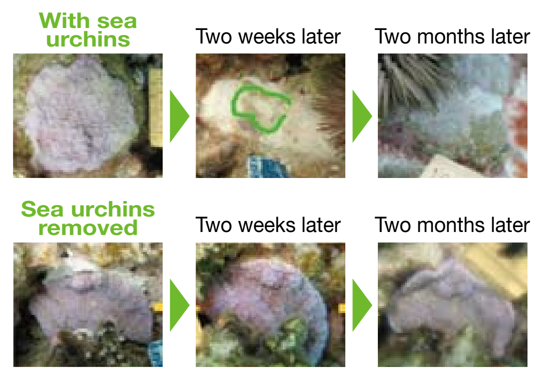
An experimental cage full of macroalgae

Studying the Relationships Between Marine Organisms and Reef Health

3. Sea urchin predation on corals

Like fish, sea urchins are considered essential for healthy coral reef growth because they consume the macroalgae that impede the growth of coral. However, a recent study by the team, found clear evidence that sea urchins can also have negative impacts on corals.

In particular, coral cover is low in certain rocky areas of the reef with high densities of the rock-boring sea urchin *Echinometra mathaei*. By conducting experiments on these parts of the reef, the team collected evidence that this species of sea urchin was also grazing on the living tissues and skeletons of three species of coral (see photographs on right).



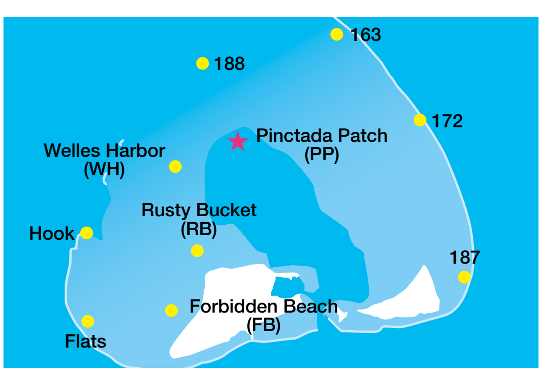
4. Recruitment and distribution of pearl oysters

Populations of black-lipped pearl oysters (*Pinctada margaritifera*) have still not recovered from excessive harvesting in the Northwestern Hawaiian Islands in the 1920s and 1930s. One ongoing research project at Midway is designed to determine the recruitment, growth and population dynamics of black-lipped pearl oysters, to evaluate the feasibility of recovery, and to develop restoration methods.

The team deployed 10 recruitment collectors at each of 10 sites around the atoll to measure the rate of recruitment, and then also counted the numbers of adult black-lipped pearl oysters. They found that recruitment rates were highest on patch reefs in the center of the atoll, especially northwest of Sand Island and in the deep lagoon.

Surveys have now discovered ten adult *P. margaritifera* on patch reefs in the deep lagoon and in the small boat harbor. This number of live adults is greater than any figure reported from Midway during the last century.

Recruitment site locations



Black-lipped pearl oyster
(*P. margaritifera*)

Program Expansion: New Projects

1. Sediments and erosion

In 2008, the team initiated sediment transport and erosion studies across Midway Atoll, by sampling sediments and rubble at over 200 sites for analysis of grain size and composition. These data are being used to produce the first-ever detailed maps of sediment distributions at Midway.

The data will also be integrated with long-term meteorological (wind direction and strength) and oceanographic (tides, sea-level anomalies) records to identify sites of erosion and sediment generation within the coral reef ecosystem, together with the routes of sediment transport and rates of deposition or loss from the reef.

The ultimate goal of this research is to determine whether Midway has the ability to grow fast enough to keep pace with sea-level rise.

2. Groundwater and nutrients

Small nutrient inputs to the coral reef are generally beneficial, stimulating the growth and productivity of many organisms. However, high concentrations of nutrients can harm corals because local areas of enrichment tend to stimulate excessive growth of algae and toxic microbes (such as cyanobacteria).

The team collected water samples from 14 monitoring wells on Sand Island, and from 22 holes up to 4 meters deep dug on the beach. Comprehensive analysis of these samples will help to identify and quantify the nutrients and contaminants flowing into the coral reef at Midway Atoll.

Global Coral Reef Conservation Project

Seychelles

Seychelles




■ Special Regional Characteristics

The Republic of the Seychelles is an island nation, located approximately 1,600 miles off the coast of East Africa in the Indian Ocean. There are about 300 to 350 species of coral in the Indian Ocean surrounding the Republic of Seychelles. In 1998, it was reported that 90% of coral found in the Seychelles had perished due to rising ocean temperatures resulting from the El Niño event.

■ Purpose of Project

To examine the reef environments of Curieuse Island to determine how they respond to environmental stress and gain a better understanding of ecology and physiology of the key components of the ecosystem.

■ Research Framework

Dr. David Smith of the University of Essex Coral Reef Research Unit, leads this Earthwatch project in a partnership between MC, the University of Essex and Earthwatch Europe.

Message From the Project Leader

Studying the response mechanisms of corals to environmental change

Dr. David Smith
Coral Reef Research Unit
University of Essex

Our research is focused on identifying management solutions for coral reefs threatened by environmental change and on understanding how both biological and social systems will respond to this stress. In particular, we are focused on investigating the vulnerability of coral reefs to the bleaching phenomena and how vulnerability varies between species and within species: we have termed this genetically constrained but environmentally regulated tolerance. Our research has demonstrated that under a certain set of environmental conditions, corals once deemed sensitive have a natural capacity to tolerate conditions that result in coral bleaching and mortality. Combined with this much applied research that will change how regulatory bodies protect coral reefs, we are also examining how local communities are equipped to deal with the change in reef-based resources predicted to occur through climate change models. Protection of natural systems and the protection of community livelihoods are our key research goal.

Studying the Response Capabilities of Corals to Environmental Change

Review of Project History and Results

How will coral reefs respond to environmental change? Environmental change can be both chronic, such as long-term climate change, as well as acute such as the well-documented periodic El Niño and La Niña events. The biggest environmental change event in recorded history occurred during 1998 when an exceptionally large El Niño caused seawater temperatures to rise across wide expanses of the tropics but particularly within the Western Indian Ocean. The Republic of the Seychelles was particularly affected with up to 75% of corals being killed in just a few months. The cause of the mass mortality event was thermal induced coral bleaching. Our research within the Seychelles was initiated in 2006 and aimed at understanding how coral reefs were affected by such events, how they respond post-event and most importantly, to identify management opportunities that would provide authorities with the best chance to strategically manage against future mass mortality events. Importantly many scientists predict that the occurrence of most severe El Niño events may well increase in the future and therefore there is a real sense of urgency to identify and implement management policies that will provide reefs of the future with the best chance of surviving future, bigger, events.

Research on Desroches

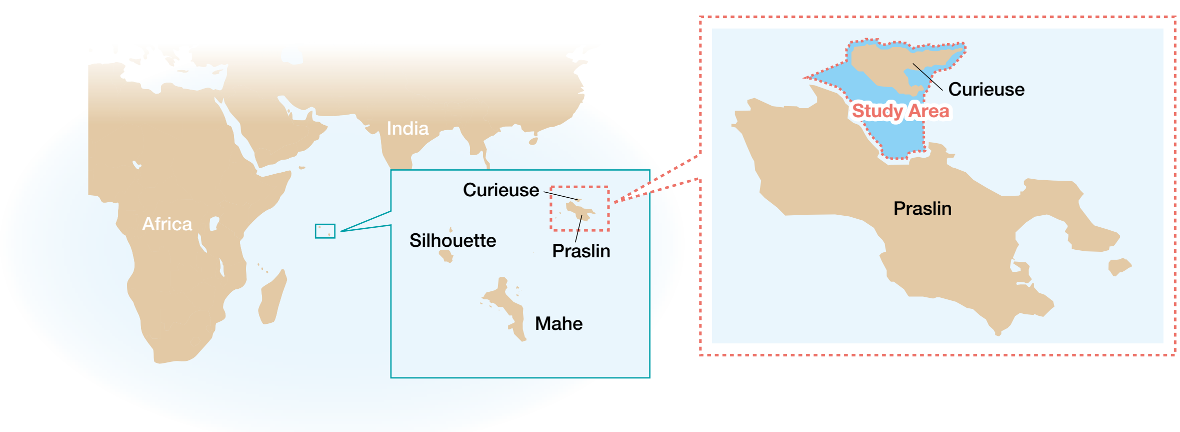
Our first research site was the remote island of Desroches. During this expedition we described the abundance, characteristics and age populations of corals across the various habitats common to the island. As may be expected the majority of coral species were much younger than the 8 years since the 1998 El Niño event but the research did demonstrate that several species did have the ability to survive and tolerate the mass bleaching episode. Of high significance, however, was the presence of previously considered sensitive coral species, of an age that demonstrated that they survived the 1998 event, existing in marginal and sub-optimal environments that were hitherto thought of as being areas of low conservation value. Clearly corals in these marginal habitats had high levels of tolerance to thermal induced bleaching that was not present in the same species from other reef habitats. We consequently hypothesised that the environmental conditions of these marginal habitats, termed *Refuge Environments*, resulted in an inherent tolerance to the acute bleaching response and the environmental conditions of these *Refuge Environments* were fully characterised.

Research on Silhouette and Curieuse

During 2007 the research moved to the granitic island of Silhouette just north of the main island of Mahe. Here again the coral community was fully characterised by the set of environmental conditions that were common to the marginal *Refuge Environments* identified in Desroches were absent and that may explain why there were no large stands of old sensitive species. Of significance however was a high abundance of small colonies of sensitive coral species on the north side of Silhouette Island. Clearly these corals had recruited into the system post the 1998 event. Of direct conservation value was the finding of a deeper reef off the north coast of Silhouette which may have acted as a refuge environment containing stands of sensitive species. We hypothesised that these reefs re-seed the more classical reef environments around northern Silhouette when environmental conditions returned to normal. The research findings from Silhouette and Desroches have major implications for management: some environments protect coral species and the natural environment buffering capacity (refuge) has the potential to re-seed other reef systems when conditions return to normal.

To test these theories in an independent environment the research moved to the Island of Curieuse in 2008. During this first field season we characterised the coral community and environmental conditions. Most importantly environments similar to the refuge systems of Desroches were identified and the detailed examination of these environments and the physiology of corals from the sub-optimal and optimal environments formed the key objectives of the next phase of research. Future research however also included detailed surveys of local dependent communities. The aim of this research was to identify the levels of dependency on reef-based resources and the number of options open for local communities to derive income and food from other sources. A biological and social science approach is essential when considering and proposing conservation management strategies.

■ Research sites around the Republic of the Seychelles: Descroches Atoll, Silhouette Island and Curieuse Island



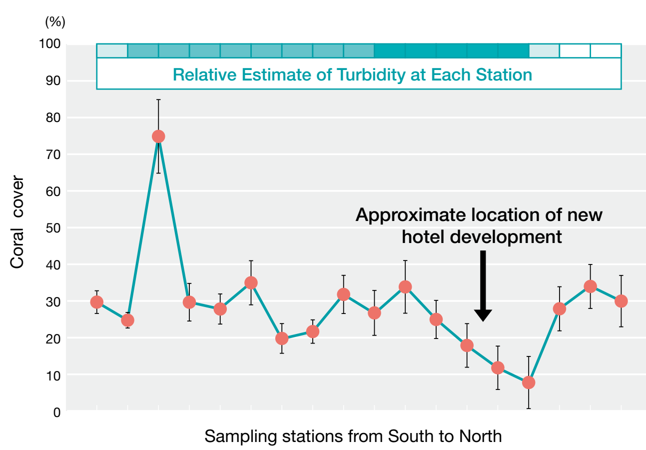
Research findings and Conclusions 2009 – 2011

1. Coral Biology

Our current research has evolved from being purely natural science based, to also incorporating a social science approach so that we could increase our understanding of the local dependency of communities on reef-based resources and how such communities would cope with reduced availability of natural resources as a consequences of climate change. Our natural science approach also progressed from base-line surveys aimed at identifying patterns of species abundance and coral age structure to characterising the physiology of corals across a range of environmental conditions. We combined these studies with experiment-based approaches that were aimed at testing the tolerance levels of corals to thermal events. Ultimately we aimed at identifying whether or not previously identified *Refuge Environments* do harbour corals that are more tolerant of thermal events thus providing opportunities for management to incorporate such *Refuge Environments* in to their management plans and protective policies. The research site at Curieuse represented a perfect natural laboratory as it is an area with a range of coral habitats and a site that has clear environmental gradients. During 2008 we identified possible *Refuge Environments* off the adjacent coast of Praslin and our first objective of 2009 was to quantify the abundance of corals across this gradient.

Relative Estimate of Turbidity at Each Station

The abundance of hard corals (means ± SE, n = 3) at 18 study stations spanning the north-east coast of Praslin within the Curieuse Marine National Park. The location of the new hotel development is shown along with a relative scale bar that indicates estimated turbidity. Colour shadings represent relative light levels of medium, high, very high, medium and low.



2. Impact on the Surrounding Environment and Coral

Coral cover varied significantly across the gradient but there are a few significant points to consider. Most importantly the site of the most coral was dominated by sensitive coral species (*Acropora* species – A). Coral cover decreased on the north side of the hotel and immediately to the south. There was evidence of negative impacts of sediment in these locations (B). Coral cover continued to decline until reaching the north-east tip of Praslin where currents were stronger, visibility increased and the system was dominated by granitic boulders and tabulate Acroporid corals. However recent mortality was high at this north site as indicated by the larger percentage of recently killed colonies (C).

There are clearly areas within this region that are able to support extreme coral cover but it would appear that the hotel development has had some negative consequences within the adjacent areas and possibly to the north which had high rates of recent (within 6 months of observation) coral mortality. The high abundance of sensitive coral species further south suggest that Curieuse Marine National Park does contain environments that may act as a refuge from thermal anomalies.

A High abundance of *Acropora* covering extensive areas of proposed *Refuge Environment*.

B Evidence of deposition sediments and nearsuface anoxic conditions in sites immediately north of the hotel development.

C Tabulate coral dominated sites at the north of Praslin with greater than 50% recently killed colonies.

Biological experiments to test the tolerance of reef building corals to thermal events

Several studies from reef communities, including those of the western Indian Ocean have identified differential susceptibility amongst key coral species to thermal stress-induced bleaching and mortality. These differences appear to generally relate to species with particular life history traits; for example fast growing, opportunistic and highly fecund coral species typically exhibit rapid loss of tissue (the host and zooxanthellae) from the underlying skeleton and therefore mortality; a bleaching response that we have termed “type-1” or “lethal.” In contrast, slower growing ‘persistent’ species exhibit relatively little obvious tissue detachment/loss from the skeleton but instead gradual paling, a bleaching response we have termed “type-2” or “sublethal.”

Consequently, continued reef functionality post-stress depends in the short term on resistance of type-2 corals but in the longer term on resilience (recruitment and re-establishment) of type-1 corals. We have observed “*historical*” evidence of resistance (as refuge/physiological tolerance) and resilience (as recruitment) during our field surveys around Desroches, Silhouette and Curieuse.

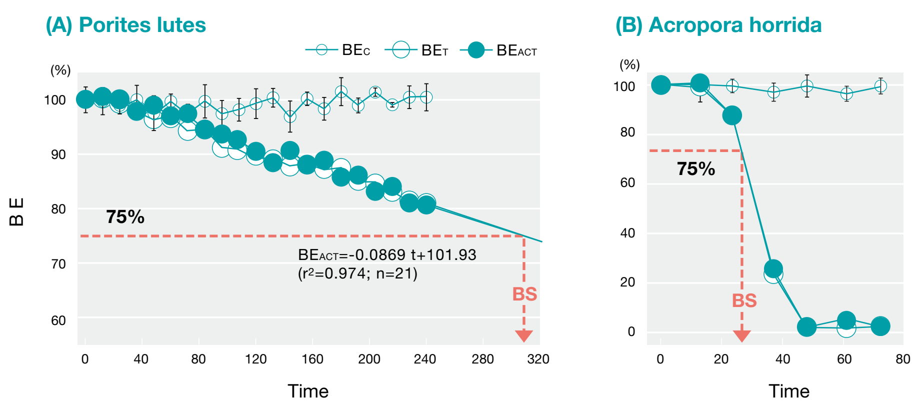
Observations of how colonies are distributed over time (age) can potentially provide estimates (the accuracy of which is dependent on localized and species specific knowledge of growth) of stress susceptibility; but estimates need to be validated with experimental testing of physiological tolerance of the species concerned. It is this “true” susceptibility, coupled with the understanding of *Refuge Environments* that is needed if we are to better predict the nature and extent of reef viability in response to future anomalies, in particular for isolated reef systems such as the Seychelles Archipelago. In this series of experiments we examined the physiological tolerance to stress (as type-1 versus type-2) and compared these results to the *in situ* age distribution (the size frequency distribution combined with growth rates), for the key reef building species. We tested and confirmed the hypothesis that these reefs would be characterized by a greater frequency of larger/older colonies of stress tolerant (type-2) species but smaller/younger colonies stress sensitive (type-1) species.

Thermal tolerance of different coral species

To complement the field research looking at coral benthic cover on different sites in the Seychelles archipelago, we conducted experiments in tanks to understand how various coral species coped with increased temperature. These experiments were conducted with 11 different species of corals at two different temperatures. One tank had a temperature similar to ambient seawater at 26°C, whilst the second tank was maintained at 32°C to determine how sensitive these coral species were to thermal stress.

All five species of Acroporidae appeared most sensitive to thermal stress at 32°C and exhibited the lowest values for BS, i.e. bleached fastest. Here, bleaching was characterized by a rapid sloughing of coral tissue in patches from the skeletal surface, a pattern consistent with a lethal type-1 bleaching response. As expected, all other species maintained at 32°C exhibited relatively high values of BS and thus appeared more stress tolerant with only a prolonged slight paling of the tissue, a pattern that is consistent with type-2 bleaching. Of most interest was the difference in sensitivity of coral species collected from different sites. The thermal tolerance of the same species of coral collected from the proposed refuge site was 4x greater than the same species collected from other reef sites. This result supports the hypothesis that certain environmental conditions enhance the tolerance of corals to thermal events as demonstrated from results obtained through field surveys undertaken in three different locations.

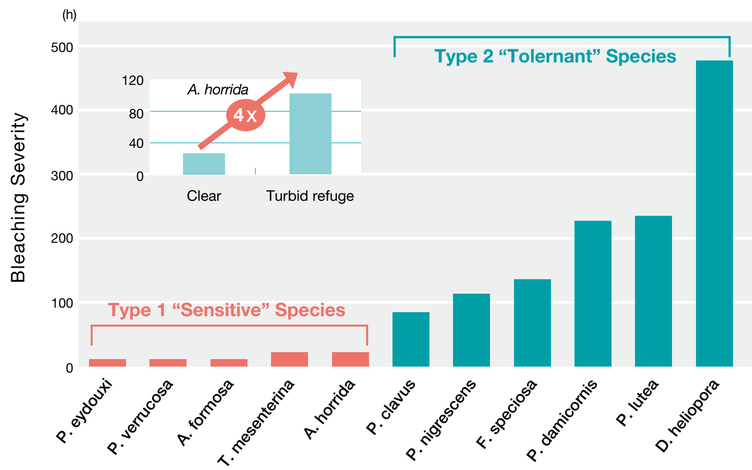
Research on Coral Response Capabilities (1)



The physiological response of two coral species to control ambient temperature (open symbols) and elevated temperature (closed symbols). A downward deflection from a starting BE value of 100% represents a decline in physiological health. BS represents the bleaching severity and is the time when BE reaches 75% of the starting value. BS therefore represents a value that reports sensitivity of corals to thermal stress with higher values suggesting tolerance.

Studying the Response Capabilities of Corals to Environmental Change

Research on Coral Response Capabilities (2)



The bleaching severity of 11 species of hard corals collected from Curieuse marine Park and subjected to a 6°C increase in temperature. High BS values demonstrate high levels of tolerance. Five of the species tested were rapidly affected by increase in temperature, referred to as Type-1 sensitive species in the figure. The variation in responses of other species was higher but none were catastrophically affected. Their physiological responses confirmed these species as being Tolerant Type-2. Inset figure represents the same experiment but for a single species (*A. horrida*) collected from two different sites. Specimen 1 was collected from sites with high light environments (Clear) whereas sample 2 was collected from the proposed Refuge site (Turbid refuge). The same y-axis labels apply and the arrow indicates the increase 4 fold increase in tolerance determined for the specimen collected from the turbid site.

Summary of natural science studies

Our study and experimental-based investigations have confirmed that reef systems of the Seychelles are still recovering from the 1998 El Niño and likely characterized by at least two distinct strategies for reef building corals to respond to environmental stress: (i) Rapid growth and high short-term fecundity at the expense of tolerance and (ii) Slow growth with low short-term fecundity but high levels of tolerance. Those coral species reliant on recovery through recruitment will inevitably be dependent on availability of *Refuge Environments* for isolated systems such as the Seychelles. Thus, incorporation of factors governing recovery, in particular strategies for surviving environmental stress and identification of *Refuge Environments*, will be critical for effective management of these systems in light of future stress events. Unfortunately *Refuge Environments* may not represent the idyllic characteristics of a coral reef and have been practically ignored in most conservation planning strategies. Our future investigations will focus on understanding the absolute drivers, both physiological and environmental, of tolerance and to identify under what conditions corals that are classified as type-1 and sensitive can be pushed to a type-2 and tolerant physiology.

Social Science Studies

The global decline in coral reef biodiversity, coupled with the likely adverse impacts of climate change, place communities which depend upon reef fisheries in a situation of high risk and uncertainty. Given this situation, there is a need to assess such communities risks not only from the perspective of natural science, such as the impact of stress on natural resources due to climate change, but also in terms of their economic and social wellbeing. The research activities in 2011 underlined the importance of preservation initiatives from the private and NGO sectors. Concurrently, communities dependent upon marine resources are declining in the face of a variety of economic and social pressures.

1. Social Science Research Update

The impacts of climate change on nearshore artisanal fisheries in Seychelles are at present uncertain. There is no consistent evidence from the literature that fish catches are approaching the maximum sustainable yield. Therefore, perturbations and stresses associated with climate change may not impact fishing activity as fish stocks are able to absorb any such stresses. However, the research did identify that nearshore fishing activities are believed by local fishers to be resulting in a diminution of catches. Our research also focused on the concerns that climate change is associated with variable catches or stock decline but this was not perceived to be a major issue in the study region. That in itself is an important finding and awareness of climate change threats and its implications for socio-ecological systems needs to be addressed.

Perhaps one of the most important characteristics of a resource dependent community is the ability of that community to self-mobilise in order to mitigate the impacts of external drivers such as climate change. It was found that resource users were able and willing to self-organise in the form of co-operatives and to use these as lobbying mechanisms. Artisanal fishers were far more likely to engage in this than commercial fishers. One reason for this may be that although they are unable to support a lobby financially, the artisanal fishers on Praslin, the location of the majority of the research work, find meaning and fulfilment in helping with conservation activities.

A main focus of our research is to identify the practicalities of introducing strategies which can mitigate the impacts of climate change on natural, financial, human or social capital. The 2011 research team identified numerous barriers to this which will inform subsequent research.

2. Summary of social science research

Social research was initiated for the first time in 2011 with initial results demonstrating the amount of further research and capacity building that is required within the study site. The biological research team has clearly demonstrated that environmental stress events can have very large effects on the diversity and productivity of natural resources utilised by local communities. The dependency of local communities on natural resources will increase in line with economic pressures and depleting commercial stocks. It might therefore be predicted that pressures on natural resources, particularly reef-based, will intensify in the short term. Clearly the communities within the study area do have the ability to adapt to changes and to coordinate activities to decrease the impact of resource depletion, but awareness of the implications of climate change on economies, natural resources and community livelihoods needs to be increased.

From the Volunteers

The Global Coral Reef Conservation Project involves MC employees and other members of the general public as volunteers to support the research activities. We asked volunteers from each of the three locations, Okinawa, Midway, and Seychelles, for their impressions and observations.

Okinawa

I have been diving for over 10 years. In 1998, when the issue of coral bleaching first came to my attention, I was extremely saddened by the idea that corals would eventually bleach and die off. There is a limit to what I can do as an individual, and for a while I wasn't able to contribute at all. When I saw that the company was looking for volunteers for this project, I decided that I absolutely wanted to participate.

I am involved in new energy and the environment through my work, so I am conscious of the environment and energy issues. I was thinking in particular about what I personally could do to combat global warming, which is affecting the earth directly. Although I was aware of the issues, that was not leading to actual action. During that time, there was an announcement in the Company magazine about the Coral Reef Conservation Project. Based on that, I got involved as a first step to taking real action on environmental issues.

This was an excellent opportunity to think long and hard about nature, the coral reefs, and the sea. I consider myself extremely lucky to have had the chance to participate in the cutting-edge research in such a wonderful place as Okinawa. In so many ways, I feel this is a wonderful project.

To be honest, I cannot tell you exactly how valuable those five days working on the project were. But what I do know is that from now on whenever there is a breakthrough discovery, it will be amazing to know that it was connected to a project that I was involved in.

A long time ago I visited places like Cancun, the Great Barrier Reef and Palau. When I heard the news that the beautiful coral reefs there had become so damaged over the past 10 years, I was deeply saddened. I consider myself very lucky to have been able to participate in this research.

I have always been interested in scientific experiments, so it was very enjoyable to work in a lab, where I wouldn't normally have the opportunity to help. This was a priceless experience, and I am grateful to have had the chance to attend the lectures by Prof. Suzuki and his colleagues.

I have learned how connected our daily lives are to the biology of the coral reefs. When I have the chance, I like to tell people about my experience in Okinawa with this project, and help them gain a deeper understanding of the issue. I am very grateful to Shizuoka University and the University of the Ryukyus for how much they have helped me in my time at the research center in Sesoko.

International Environmental NGO Earthwatch Japan
Shigeo Yasuda, Executive Director

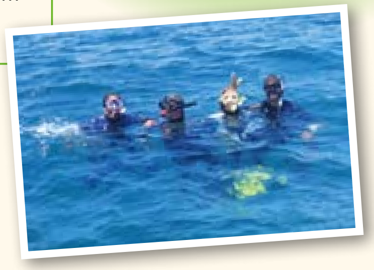
Earthwatch Japan has sent volunteers who are ordinary citizens to the field research sites to help researchers with their survey work. Through this assistance, we aim to help other people learn more about the Earth today.

We are delighted to lend a hand with the coral conservation research under the leadership of research scientists and academics from Shizuoka University and the University of the Ryukyus. We thank Mitsubishi Corporation for helping make this happen. Through these activities, we hope that many people will learn about the current state of coral reefs as well as the diligent efforts of project researchers.

Midway

Thanks to my experience with the coral reef, I have been making an effort to change my own lifestyle. Specifically, I've been avoiding driving, as well as reusing plastic bags and shopping responsibly. And when I see people doing something harmful to the environment, I point it out to them.

Through this project, I was able to experience various kinds of work. The tasks I performed ran the entire gamut, from physical labor, such as filling scuba tanks and preparing, repairing and cleaning other equipment, to collecting samples and data at the research sites, and helping to confirm and write up results.



This volunteer program was physically tough, but it gave me an amazing opportunity to participate in scientific ocean research in a unique and beautiful environment with other volunteers from every sort of background and profession. I would definitely recommend it to others.

These activities taught me how delicate the balance is between a healthy ocean and the natural changes that occur. I understood for the first time how much damage human beings have done to nature. We should treasure the Earth, our oceans, and our skies. It is not enough that they last for our lifetimes—we should make sure they are around for eternity.

Seychelles

During my trip, I learnt about how coral reefs benefit the environment and people in numerous ways. They protect shores from the impact of waves and storms, and provide benefits to humans in the form of food and medicine. They are the greatest expression of ocean life, and the most diverse ecosystem on earth!

We checked, monitored and measured approximately 13,440 m² of sea floor; we identified more than 62,000 fish from 59 different species; and saw the response of coral to water temperature. We are told that the material gathered will be analyzed further by the scientists upon return, and that they should generate even more interesting results.

To me, the project is almost like doing a behind-the-stage tour in an opera house. Seeing the show onstage is a fabulous experience - learning about what sustains it is even more so. Waiting for the boat home, I try to focus on the joy of having been there; not on the sadness of saying goodbye.

International Environmental NGO Earthwatch Europe
Nigel Winser, Executive Director

In 2012, Earthwatch and MC celebrate our 20th anniversary. At this landmark year, it gives me great pride to see how this partnership is flourishing; now supporting leading marine research at three locations worldwide. This work has never been more important as the pressures facing our oceans continue to grow. Coral reefs - one of the richest ecosystems on Earth - face a multitude of challenges, both local and global, many of which are related to human activities. It is partnerships like this that enable Earthwatch to undertake its mission, with increasing energy, enthusiasm and action by volunteers from all around the world. This in turn empowers our leading scientists to shape the future of our oceans. We are indebted to our colleagues at MC for this continuing commitment.

Mitsubishi Corporation

Mitsubishi Corporation
Global Coral Reef Conservation Project

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