Impact Objective

- Conduct research on oceans, geology and related organisms
- Contribute to the development of science and science education

Coral research helps predict the future

President of KIKAI Institute for Coral Reef Sciences, Professor Tsuyoshi Watanabe *and* Director Dr Atsuko Yamazaki *share their work on reconstructing past climate and oceanic conditions using coral cores, the importance of coral reef research and the projects highlights and challenges*

Professor Tsuyoshi Watanabe

Director Dr Atsuko Yamazaki

Can you outline the purpose of your research at the KIKAI Institute for Coral Reef Sciences?

AY: The main purpose of our research is to understand marine ecosystems and biogeochemical cycles, and to reconstruct past climate change at human society-relevant timescales, daily to monthly scale at century length. Modern and fossil coral records provide information of climate, ocean chemical and physical changes and their responses towards environmental changes with monthly time resolution.

From your perspective, why is it valuable to collect, study and store coral cores?

TW: It is important to obtain direct evidence to see how the climate has been actually changing in the past and how it has influenced coral reef ecosystems, however, long term observations and instrumental records are very limited, especially in tropical areas. Therefore, time series data recorded by corals is highly important to understand past climate change and its influence on reef ecology. For example, Sea-surface temperature (SST) records provided by coral cores from the preindustrial era have been used for future climate predictions. We have established a coral core centre to store the coral cores and climate data from the Indo-Pacific, and to encourage collaboration works amongst scientists.

What are the main highlights of the project to date?

TW: We are obtaining coral samples from a wide area of tropical to temperate regions in the world, including Indian and Pacific Oceans and the Caribbean Sea, and we are also recently working on sites around Japan in north-western pacific with large latitudinal and environmental gradients along the Kuroshio current, these areas have large differences in temperature, nutrient, pH, pCO_2 (Partial Pressure of Carbon Dioxide). Coral ecosystems from tropical to temperate regions are sensitive to climate changes in recent global warming and ocean acidification periods. We collected living and fossil coral cores from north western pacific regions and found that El Nino existed and was maybe more active in Pliocene warmth. This time era is thought to be similar conditions in which we will face next century as the result of global warming. For example: the Kuroshio current transportation has been getting more stable and stronger during the last 150 years with recent global warming; the Kuroshio current is the largest current in the world and is important to sustain marine ecosystems, including coral reefs; and the Asian summer monsoon could be the driving force of Pacific Decadal Oscillation (PDO) variability. The Asian monsoon is a key component for driving global climate systems, including in the Pacific Ocean.

Can you explain what makes Kikai-jima (Kikai Island) such an important site for the geology of coral reefs?

TW: Kikai-jima is an uplifted coral reef island with the second largest uplift speed in the world. We can see past coral reef environments and ecology through the last 100 thousand years continuously. During these 100 kilo years, our planet had experienced global cooling (last glacial maximum) and warming (Eemian). The information from past coral reefs provides the future image of coral reefs with climate changes. Also, Kikai Island is located at the boundary between tropical and temperate regions. It is ecologically and oceanographically important to examine and monitor coral reef conditions with changing climate, currently and in the future.

Have there been challenges the project has faced? How did you overcome these?

AY: We found it challenging to establish a field based and self-financed institute on Kikai Island. In many cases, field based science has been done only to collect samples and information in field sites, and then to analyse and publish in their home-town after bringing them back. Such traditional ways have led to situations where local and young people could not share scientific and educational benefits. We also recognised the recent threat of science and education in the national university and institute facing strong bias from economic and political situations. Our cutting edge and pure sciences should be free from any other political and economic situation. We try to be independent by being a self-organised and self-financed organisation based on multi discipline sciences from voluntary scientists with a local and international framework.

Collaborating on the future of coral reefs

By utilising coral cores, including collection, analysis and storage solutions on Kikai Island and Hokkaido University, *the* KIKAI Institute for Coral Reef Sciences *is bringing together a range of people and scientists for collaborative research to understand the past and future of coral reef ecosystems*

Coral reefs have existed for at least 500 million years, but in modern times anthropogenic impacts such as, global warming, ocean acidification, coastal development and marine pollution threaten the world's coral reefs. To predict the future of coral reefs we are required to look back into the past to see how coral reefs have evolved to cope with changing climatic and oceanic conditions and how those changes have led to what we know about coral reef ecosystems today.

To unlock the mysteries of coral history the KIKAI Institute for Coral Reef Sciences was established. The KIKAI Institute is located on the beautiful Kikai Island in the Amami region of Japan on extraordinary uplifted coral reefs, which border tropical and temperate regions. Since 2014 the field-based and self-financed institute, in association with the Coral Reef Environmental Earth Sciences Lab (CREES) at Hokkaido University, has provided a place for cutting edge science and the inclusion of current and the next generation of scientists.

Science education program "Coral reef science camp"

Through collection, analysis and storage of coral cores Professor Tsuyoshi Watanabe, president of the KIKAI Institute for Coral Reef Sciences, alongside Institute Director Dr Atsuko Yamazaki, envision a future where coral reef science is free from political and economic influence. Watanabe says it is a place which is inclusive of more people and scientists with different ideas and backgrounds who can come together for joint ventures to 'sustain our scientific and educational goals and to protect coral reef ecosystems for the future'.

BENEFITS OF CORAL CORES

To respond to the needs of the project the coral core centre was established at KIKAI Institute on Kikai Island, Japan and Hokkaido University, Sapporo, Japan. Yamazaki explains the mission is to 'reconstruct past environmental and climatic changes with century scale and high temporal resolution throughout tropical to subtropical sea surface, which are essential to predict future conditions in a warming earth'.

The coral core centre provides a place where a range of technical support can be supplied for coral research and which presents an opportunity for joint research. The facility has cutting edge scientific equipment for assistance in coral drilling, coral cutting and mining, image analysis, geochemical analysis, coral core depository and the facility also holds a coral core data base and coral core samples for future collaborations. Providing a place where this technology can be accessed helps with keeping down costs and risks associated with coral core collection and analysis, and by storing the coral cores and allowing other scientists to access samples and data, damage is minimised to the coral itself and allows for effective utilisation of research, time and costs.

Watanabe explains the kind of technology that is involved to reconstruct past conditions from coral cores. 'We have an applied geochemical analysis using a mass spectrometer and other instruments to reconstruct changes in past environments and physical measurements and observation of skeletal structure and property using microscope, SEM, and x-ray CT and so on,' he says. 'Oxygen isotopes have been most widely used to reconstruct past changes in surrounding temperature and salinity; strontium/calcium ratio for temperature, carbon isotopes for sun light and/or activities in coral and symbiotic algae, lead isotope for atmosphere pollution, barium/calcium ratio for river discharge and terrestrial input, boron isotope for ocean pH, and nitrogen isotope for nutrients. Skeletal parameters such as, density, calcification rate and extension rate, provide the change in coral growth and ecological changes in reefs.'

ENGAGING PUBLIC AND SCIENCE

In addition to running scientific research at KIKAI Institute the facility runs educational activities, events and invites the public over to the island to engage with current research at the island's science café. Part of the educational activities on the island is a five day coral reef science camp where children can immerse themselves in a range of coral related activities. 'We provide the opportunity for children and students to meet the first-class scientists and to experience real research with 'alive' scientific materials in Kikai Island. For example, we organise summer science camps, inviting children from outside and inside the island and also scientists working on coral reefs in order to raise the next generation of leaders of coral reef researchers through encounters with current leaders and the true nature in Kikai-jima,' explains Watanabe.

> "We provide the opportunity for children and students to meet the first-class scientists and to experience real research with 'alive' scientific materials in Kikai Island"

With this approach KIKAI Institute encourages outreach of new ideas and excitement through all kinds of people, even if they are or are not scientists. 'With the advantage of the unique geological and environmental setting and location of our institute, more people from wider areas with different scientific and technological backgrounds, such as geologists, ecologists, geochemists, and archeologists, will visit this island and lead the new findings and linkages with reaction amongst different ideas and methods,' Yamazaki says. 'We believe that such international and multidisciplinary collaboration and interactions will lead break-through finding and education for the next generation of leaders.'

SUCCESSFUL OUTCOMES AND FUTURE GOALS

KIKAI Institute for coral reef sciences has already produced exciting results from research conducted at their facilities. 'We have recently developed new methods to analyse nitrogen isotopes in coral skeletons to reconstruct nutrient dynamics in surface water and eventually to reconstruct the past history of the Kuroshio Current,' says Yamazaki. 'Kuroshio transportation is getting more stable and stronger during the last 150 years with recent global warming.' This result is an exciting find because the Kuroshio Current is the largest current in the world and is important in sustaining coral reefs and other ecosystems.

Additional research has found that key processes such as El Nino existed and was possibly more active in Pliocene warmth and that the Asian summer monsoon could be the driving force of PDO variability. Watanabe points out that these results are significant to coral reef ecosystems because 'the Pliocene era is thought to be similar conditions in which we will face in the next century as the result of global warming and the Asian monsoon is a key component for driving global climate system, including the Pacific Ocean'.

The future of research at the Institute includes an understanding of 'GeoEcoMonitoring'. 'Geological and ecological monitoring and analysing modern and past coral reefs, including geological and ecological surveys on land and under the ocean, and analysing chemical composition of coral and sea water, to capture the full history of change in climate and coral ecosystems through different climate systems to predict a future way for co-existence of corals and human beings,' explains Watanabe. The team also hopes to further advance the understanding and research of coral reefs by inviting more people out to the island to be involved in science and activities on the island.

Project Insights

CONTACT
Tsuyoshi Watanabe
President
KIKAI Institute for coral reef sciences

T: +81 997660200
E: mail@kikaireefs.org
W: http://kikaireefs.org/

PROJECT COORDINATOR BIOS

Professor Tsuyoshi Watanabe started in coral research in Hokkaido University with BS in 1994 and a MS in 1996. He graduated with a PhD in environmental earth science in 1999 and continued to study on the corals in Australia, France, Germany and US. His present affiliation is Department of Science in Hokkaido University as a senior lecturer.

Dr Atsuko Yamazaki was involved in coral research in Hokkaido University from BS in 2008, a MS in 2010, and Ph.D in 2013, under the supervision of Watanabe. Her interest is reef coral evolution related with biogeochemical cycles and climate changes. Yamazaki's present affiliation is Department of Science in Hokkaido University as assistant professor.

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KIKAI institute for Coral Reef Sciences 喜界島サンゴ礁科学研究所

Coral Core Center