Marine ecosystems after Great East Japan Earthquake in 2011

Our knowledge acquired by TEAMS

Edited by Kazuhiro Kogure, Masato Hirose, Hiroshi Kitazato and Akihiro Kijima

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1. Preface

Akihiro KIJIMA   Tohoku University

The Great East Japan Earthquake and tsunami 5 years ago, on March 11, 2011, caused immense damage to marine ecosystems, both nearshore and offshore, on the Pacific coast of northeastern Japan (the Tohoku area). Debris was deposited far inland and into the subtidal zone; crude oil and other toxic chemical compounds spewed into the ocean; and seaweed forests and tidelands were obliterated. Marine products (fisheries and aquaculture) are the mainstay of industry in Tohoku but most fishing vessels, fishing gear, aquaculture equipment and nets, and onshore facilities for processing marine products were destroyed. Although five years have passed since the disastrous earthquake and tsunami, the rebuilding of towns and recovering of fisheries is proceeding slowly because of the extensive devastation. Therefore, helping the restoration of marine ecosystems and revitalizing the fishing and marine-product industries in these coastal areas have become a pressing issue. In order to accomplish these urgent tasks, as well as to learn how to cope with such disasters in the future, scientific investigation is essential to understand the effects of such strong disturbances on marine ecosystems and to monitor the process of their recovery.

The Tohoku Ecosystem-Associated Marine Science (TEAMS) project is a decade-long project to monitor and aid the restoration of marine products in the area by conducting scientific research to clarify the means by which marine bio-resources can be efficiently but sustainably exploited. It is funded by the Ministry of Education, Culture, Sports, Science and Technology in Japan (MEXT). Tohoku University is the central representative member, in collaboration with the Atmosphere and Ocean Research Institute (AORI), the University of Tokyo and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Over 200 marine researchers from all over the country are involved. The marine environments and ecosystems are being continuously investigated from coastline to offshore and from surface to bottom throughout the water column along the Pacific coast of the Tohoku area. The results obtained are open to fishery-related organizations, local governments, and ordinary citizens through regular series of public lectures and symposia.

The TEAMS project includes the construction of a database contributing to the coordination, management and research of future large-scale disasters within the global community. The project will also contribute to future integration and synthesis of research in marine and fishery sciences. Although TEAMS intends to advocate "science that contributes to society (Science for Society)", and to push forward with maximum effort, this group of scientists alone cannot bring about recovery and revival following such an historical catastrophic disaster. Your kind understanding, cooperation, guidance, and encouragement are also important contributions to enable us to continue meaningful scientific monitoring activities, by which we hope to aid the rebirth of this part of Japan and contribute to the human knowledge base in how to cope with similar such disasters wherever in the world they occur in the future.

In the above point of view, TEAMS is holding an international symposium in Tokyo in March, 2016. The results obtained by TEAMS research activities during the last 5 years have been compiled in this book that would be released at the symposium. It is expected that this book will serve as disaster prevention guide to earthquake affected parts in the world, contribute to disaster reduction, and serve as a guide towards building infrastructure.

2. Great East Japan Earthquake (GEJE)

Sheryl O. FERNANDES & Kazuhiro KOGURE AORI, the University of Tokyo

2-1 The earthquake and subsequent tsunami on March 11, 2011

Every day, roughly 300 earthquakes are felt somewhere in Japan (http://www.hinet.bosai.go.jp/hypomap/?ft=1& LANG=en). Historically, earthquakes with magnitude larger than 8 have struck Japan every 30-40 years. This is due to the existence of hundreds of active faults embedded throughout the country as well as the continental and oceanic plates (Yamasaki, 2012). The Japanese Islands lie at the junction of four major tectonic plates – the Pacific and the Philippine Sea oceanic plates and the North American (or Okhotsk) and the Eurasian (or Amurian) continental plates. The Pacific plate descends underneath the North America plate at the Japan and Kurile Trenches at a rate of up to 92 mm y^{-1} (Wei and Seno, 1998; Sella et al., 2002). The Japan Trench lies in the floor of the northern Pacific Ocean and is located east of Tohoku (north-eastern Honshu).

On March 11, 2011, 14:46:23 Japan Standard Time, thrust faulting on or near the subduction zone plate boundary between the Pacific and North America plates (axis of the Japan trench) resulted in magnitude 9.0 earthquake. This 130 second earthquake was the most powerful known to hit Japan and the fifth-most powerful quake ever recorded. It's epicenter was located 70 kilometers off the coast of Miyagi prefecture, a part of the Tohoku region. The rupture area of the Tohoku-Oki earthquake extended approximately 450 Km long and 150 Km wide (Mori et al., 2011). A 24 m horizontal and a 3 m vertical displacement of the sea floor was created at the epicenter (Kodaira et al., 2012). The relatively shallow depth (24 km) of the quake (JMA, 2011) caused a gradual increase of sea level by about 2 m followed by an impulsive tsunami wave of 3 to 5 m (Fujii et al., 2011). The tsunami waves traveled at a speed of about 700 kilometers per hour reaching the Japanese mainland within 25-30 minutes. It eventually struck several other locations in the Pacific Ocean viz., Hawaii, California, Oregon, Washington and British Columbia.

2-2 Overview of damage caused by the tsunami in Tohoku region

The earthquake-prone country of Japan is a pioneer in disaster management. The Japan Meteorological Agency (JMA) issued a tsunami warning 3 minutes after the earthquake and revised it several times after getting real time seismic and tsunami data (Imamura and Anawat, 2012). Also, Japanese media channels and mobile phone networks broadcasted tsunami warnings which enabled people to flee to higher elevation. Japan has spent billions of dollars on construction of breakwaters and anti-tsunami walls in vulnerable regions along the Sanriku coastline.

However, the tsunami generated by Great East Japan Earthquake (GEJE) was so overpowering that it overtopped some seawalls causing destruction to many of these structures. Large-scale devastation on land was inevitable. The effects were felt in the northern Aomori prefecture to as far as Chiba prefecture in the south. Waves of up to 39 meters (The 2011 Tohoku Earthquake Tsunami Joint Survey Group, 2011) pounded the eastern coast of Tohoku destroying towns, villages and flooding areas more than 5 km inland. The tsunami inundation depth was as high as a two storeyed building. According to latest updates available from the National Police Agency, 15, 893 people lost their lives, ~ 2,572 were reported missing. About 26,992 individuals were injured across twenty prefectures (Zaré and Ghaychi Afrouz, 2012). The highest numbers of fatalities (57 %) were reported in Miyagi prefecture followed by Iwate prefecture (33 %) and Fukushima prefecture (9%) (Mori et al., 2011). This was because of shorter distances from the epicenter and the tsunami propagation vector was directly perpendicular to the shoreline direction in these prefectures (Lekkas et al., 2011). In Onagawa (Miyagi prefecture), highest tsunami run-up (maximum vertical elevation of a point on initially dry land that is inundated by the waves) of 42 m was recorded. This has been largely attributed to the ria coast land morphology wherein narrow, short, funnel-like valleys reached the coastline with a direction parallel to the tsunami propagation vector causing a funneling-effect (Lekkas et al., 2011).

Apart from the enormous death toll, more than 125000 building were ruined. Sweeping away of building materials, vehicles, boats, trees, consumables, etc. generated more than 22,633,000 tons of debris (Imamura and Anawat, 2012). Eruption of large fires was observed in several buildings. Over 240,000 households served by the Tōhoku Electric Power (TEP) in northeastern Japan experienced blackouts while over 1.4 million suffered interruption in water supply for many days (Tsimopoulou, 2012). A 220,000-barrel per-day oil refinery of Cosmo Oil Company was set on fire by the quake at Ichihara, Chiba Prefecture, to the east of Tokyo (Tsimopoulou, 2012). In Sendai, a 145,000-barrel per day refinery owned by the largest refiner in Japan, JX Nippon Oil & Energy, was also set ablaze by the quake. Tsunami flooding caused extensive damage to the Fukushima Daiichi nuclear power plant destroying the diesel backup power system, failure of cooling system and multiple meltdowns. Venting of gases, hydrogen explosions, and the fire in the spent fuel pond of Unit 4 resulted in atmospheric release of radionuclide contaminants (Buesseler et al., 2011). In addition, cooling of the reactors with fresh water and seawater, and release of highly contaminated water from the damaged reactor buildings led to radioactive discharges directly to the sea (Buesseler et al., 2011; Kawamura et al., 2011). This was termed as the second-worst nuclear accident after the Chernobyl disaster. Japan declared a state of emergency resulting in the evacuation of nearby residents.

Major disruptions in transportation services occurred due to damage caused to the Tōhoku Expressway, flooding of the Sendai airport, suspension of operations at the Narita and Haneda airports. The early warning system resulted in a suspension of train services around Japan. All high speed bullet trains (Shinkansen) were automatically stopped preventing derailment. JR East train lines suffered damage in the worst-affected areas wherein 23 stations on 7 lines being affected or washed away by the tsunami, with damage or loss of track in 680 locations (Imamura and Anawat, 2012). Derailment of a four-car train on the Senseki line was reported. A total of 319 fishing ports were damaged in the disaster (Imamura and Anawat, 2012). The cabinet office estimated direct damage from the disaster to be approximately 16.7 trillion yen. According to the Ministry of Economy, Trade and Industry, the overall loss to the Japanese economy along the Pacific Ocean coast was about 2.5% of the total economy (265.6 trillion yen).

2-3 Damage to fisheries due to GEJE

Before looking at data on the damage caused by GEJE, it is noteworthy to summarize recent general situation of Japanese fishery industries.

First, traditionally, fish or aquatic products used to be the major protein sources for daily foodstuffs in Japan. Since 60^{th}, however, the relative share of them steadily decreased with concomitant increase of meats. After 2010, more meats are consumed than fishes.

Second, it is known that the total worldwide production of marine fishery resources has declined gradually after reaching a peak in landings in 1996 (FAO 2011). In Western Pacific area, nominal catches increased to 24 million tons in 1996 and 1997, followed by a general decline from 1988 to 1994. Catches have since stabilized at about 20 million tons. Japan used to be the largest fishery country in this area and landed about 10 million tons each year in the 1980s. However, it dropped rapidly in the 1990s and has remained at about 4 million tons a year in the last decade.

Third, although the catch is declining, price of fish or fisheries products did not increase but remained rather constant. This means that fishermen have to increase their efforts to catch fishes to maintain their income. This situation is partly due to the change of the distribution pattern from fishermen to consumers. In 70^{th}, fish was usually sold to individual retailers. In the last three decades, number of retailers decreased drastically and now two-thirds of the fish catch is sold in supermarkets. Therefore, supermarkets tend to control the price and species of fishes to sell. Their requests may not always match what fishermen catch depending on the season and fluctuation of bioresources.

Fourth, in the last three decades, the number of fishermen decreased approximately by 60%. This is accompanied with increase of their average age. For instance, in 1998 the relative portion of those over 55 years old was 48.4% whereas that in 2013, 60.3%. (2013 Census of Fisheries, 2015). It has become increasingly difficult to find young successors. Unfortunately, fishery is not an attractive industry for young people any more.

Fifth, traditionally, fisheries in Japan have been supported by local communities in coastal areas. The community is a consortium of fishermen, industry for fishing boats or gears, fish processing companies, market and so on. Those communities usually had unique cultures. However, many local communities in Japan are collapsing due to urbanization or changes in lifestyle. Young people tend to move out to cities to seek better life and educations, leaving old people in the local town.

Under such conditions, GEJE hit Tohoku area. GEJE destroyed not only the buildings and facilities for fisheries, but also the communities that were essential for the fisheries. Therefore, the restoration of fisheries is not simply done by the construction of infrastructures in local town.

A basic description of the damages in Tohoku area has been given below.

The earthquake and tsunami hit the coastal line in Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba prefectures (Fig. 1), and caused serious damages to the port, fishing boats, fishing gears, facilities for food processing and others. High relative shares of these six prefectures (Table 1) indicate that Tohoku area is an important fishery ground for Japan.

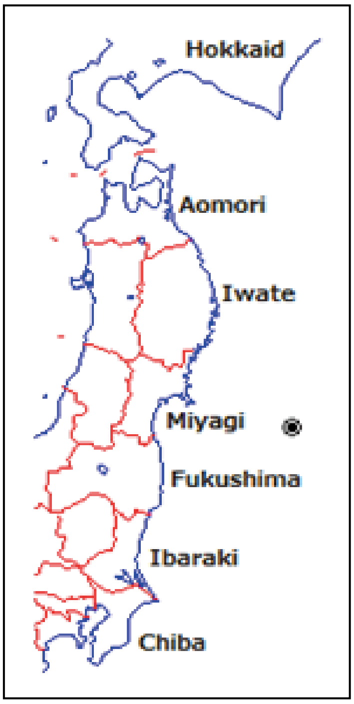


Fig. 1 Prefectures in Hokkaido, Tohoku (Aomori, Iwate, Miyagi and Fukushima) and Kanto (Ibaraki, and Chiba) areas. The dot east of Miyagi is the epicenter.

Table 1. Shares of fisheries and aquaculture production volumes from Aomori to Chiba Prefectures

Total fishery production ---	22%
Major fish group	
saury	40
anchovy	40
mackerel	38
sardine	56
cod	45
squid	48
shark	63
Aquaculture	
Total	18
kelp	33
oyster	29
wakame seaweed	79
sea squirt	96

Source: MAFF (Ministry of Agriculture, Forestry and Fisheries) Monthly Statistics of Fishery and Aquaculture Production (2009), http://www.maff.go.jp/e/tokei/kikaku/monthly_e/

Table 2. Damages to industries in Japan due to GEJE

Items	Numbers	Amount of damage (Billion yen)
Fisheries		
Fishing boat	28,612	182.2
Port	319	823
Aqua culture facilities		73.8
Aqua culture products		59.7
Related facilities	1,725	124.9
Semi total		1,263.7
Agriculture		904.9
Forestry		215.5
Total		2,384.1

Source: same as Table 1.

Table 2 shows the amount of damages to primary industries, i.e., fisheries, agriculture and forestry due to GEJE. Among the three, fisheries share more than half of the total. However, it is noteworthy that agriculture in Tohoku area is a much bigger industry than fisheries. As for fisheries, the damages incurred to each item have been listed. The damage caused to fishing ports were especially serious. In the prefectures shown in Fig. 1 there were 730 fishing ports, and nearly half have suffered. Damages were especially serious in Iwate (108 out of 111 ports), Miyagi (142 out of 142 ports) and Fukushima (10 out of 10 ports) prefectures. Although this was mainly due to physical destruction by tsunami, the subsidence, usually 50-70cm in the wide coastal areas made the ports difficult to use (Tanaka et al. 2012).

Table 3 Damages to aquacultures in each prefecture

Prefecture	Damages		Organisms suffered
	facilities	product	
Hokkaido	9,356	5,771	scallops, oyster kelp, wakame
Aomori	43	19	scallops, kelp
Iwate	13,087	13,174	scallops,oyster, kelp, wakame
Miyagi	48,700	33,189	scallops, oyster salmon, kelp wakame, laver sea squirt,
Fukushima	297	536	laver
Ibaraki	27	---	carp, pearl
Chiba	428	737	laver

Source: same as Table 1

Table 3 shows the damages to aqua culture in the six prefectures. Scallops, oyster, sea squirt, kelp and wakame seaweed are major products in the area.
These data indicate serious damages to the fishery facilities such as port, boats, fishing gears and processing plant. It is noteworthy that even before GEJE, fisheries in Japan had been facing problems. First, amount of fish or natural bioresources in the ocean had been decreasing due to overfishing or environmental changes.

2-4 Effect of tsunami on the marine environment

Significant environmental damage was reported along the Pacific coastal regions in Tohoku. Based on impact assessment report by the Biodiversity Center of Japan (Nature Conservation Bureau, Ministry of the Environment) in 2013, large parts of the vegetation in sand dunes, tidal flats and salt marshes growing along sandy beaches in Gamo region, Sendai were washed away. After the earthquake and tsunami, the shoreline receded by up to 200 m inland. This resulted in a change in shape of the sandy beaches. Weeds have now grown abundantly in areas damaged by the tsunami. Reed (*Phragmitetea*) and black pine (*Pinus thunbergii*) vegetation have decreased along affected parts in the Tohoku region. Wetlands in Watari town, Miyagi prefecture were submerged under seawater. Large scale changes to benthic organisms were recorded in the Sanriku coast due to submergence of tidal flats. Due to disappearance of the sand bar near the Unosumai river in Iwate prefecture, brackish water bivalves like *Nuttallia japonica*, *Laternula marilina*, *Ruditapes philippinarum* and *Mya arenaria oonogai* moved into inundated agricultural land. The changes in benthos were less pronounced in the Aomori coast, Sendai and Matshushima Bays, Mangokuura and east coast of the Boso peninsula. Subsidence of land by up to 1 m following the earthquake caused large tracts of seagrass beds comprising mainly of *Zostera* sp. to disappear in Hirota Bay, Mangokuura, Matsushima Bay, Otsuchi.

3. TEAMS: Tohoku Ecosystem-Associated Marine Sciences

Akihiro KIJIMA Tohoku University
Kazuhiro KOGURE AORI, the University of Tokyo
Hiroshi KITAZATO JAMSTEC

3-1 History and purpose

There was an urgent need to ascertain the impact of the earthquake and tsunami on marine biota, observe subsequent transition process of the aquatic system and restore the coastal ecosystems and fisheries in Tohoku coastal area. Although several groups started to conduct research independently in the area within a few months after the earthquake, collaborative works that cover the whole area, ecosystems, and organisms with consistent ways had been required to meet the needs.

In the Japanese Ministry of Education, Culture, Sports, Science and Technology

(MEXT), members belonging to Subdivision on Ocean Development, Council for Science and Technology discussed how to deal with the Great East Japan Earthquake and a report titled "The state of research on marine bioresources" was announced to the public on September 16, 2011. The report pointed out the necessity of the formation of a network of marine science researchers in universities and research institutes all over Japan. The establishment of a center for marine science in the Tohoku region was envisaged, on which the network is based, to continuously and systematically promote research and development in the Pacific coastal areas of the Tohoku region.

After the report from MEXT, scientists from Tohoku University, Atmosphere and Ocean Research Institute (AORI), the University of Tokyo, and Japan Agency for Marine-Earth Science and Technology (JAMSTEC) gathered and started to exchange the idea for a possible long-term project. Tohoku University had maintained Integrated Marine Field Station (IMFS) in Onagawa city, Miyagi iprefecture since 1939, and AORI had Internationals Coastal Research Center (ICRC) in Otsuchi town, Iwate prefecture since 1973. Although both centers were almost completely destroyed by the tsunami, a considerable amount of scientific knowledge on the ecosystems and living organisms in Onagawa and Otsuchi bays had been accumulated after research activities for many years. Such knowledge and facilities seemed to be suitable and vital as the center for long term research to clarify the environmental change after GEJE. Furthermore, both centers had built up close connections with local people, especially fishermen in respective area. On the other hand, the effects of GEJE were expected to extend to wide areas off Tohoku including benthic ecosystems. As JAMSTEC had scientific experience, facilities and knowledges on such specific environments, the formation of network together with JAMSTEC seemed to be reasonable. The proposal of a 10 years project, Tohoku Ecosystem-Associated Marine Sciences (TEAMS) was thus made by Tohoku University, AORI and JAMSTEC and submitted to MEXT in November 2011 and adopted by the end of 2011. TEAMS was launched in January 2012.

The purpose of the research program is to clarify the impacts of the earthquake and subsequent tsunami on the marine ecosystems of the Tohoku coastal areas, highlight the restoration process of the ecosystems from a scientific aspect, and contribute to the reconstruction of the fishing industry in the Tohoku region.

3-2 Organization

All three institutions, i.e., Tohoku University, AORI and JAMSTEC had conducted marine research for different areas and target environments, living organisms and viewpoints. We intended to conduct our long-term research by combining such different approaches. Furthermore, other scientists or institutions that had experiences of research in Tohoku area or marine environments also participated. Altogether, more than 200 scientists from all over Japan have conducted research together. As is shown in Fig. 2, we set four major projects as follows.

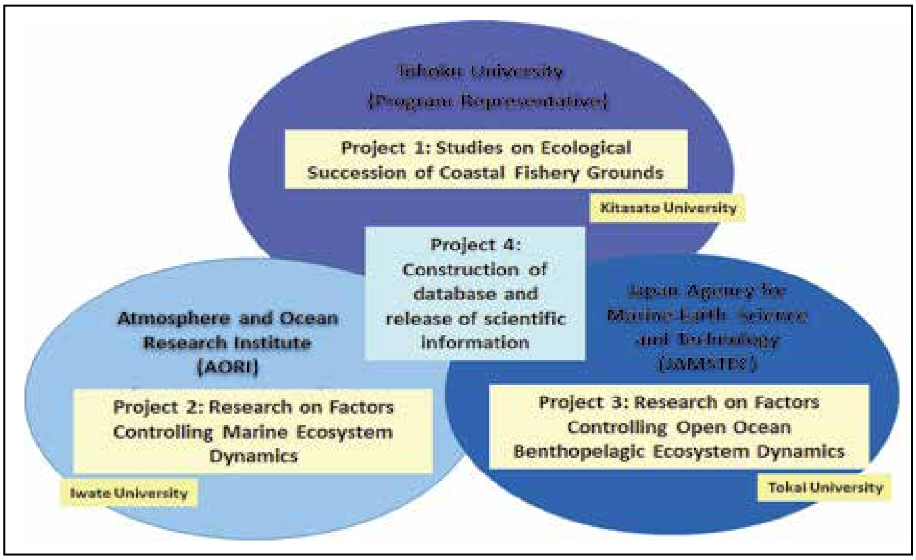


Fig. 2. Organization of TEAMS.

1) Impacts on the fisheries ground and subsequent succession

Conducted by Tohoku University in collaboration with Kitasato University.

This project aimed to first establish a base in Onagawa Bay by re-building the Integrated Marine Field Station (IMFS) in Onagawa and conduct intensive research on the fishery ground in the bay and adjacent area. It investigates the ecosystems within seaweed beds and tidal flats along the southern part of the Sanriku coast, particularly in Onagawa Bay and Sendai Bay, to elucidate the state of the fishery resources and to clarify the restoration process of the fishery resources.

2) Factors controlling marine ecosystem dynamics

Conducted by AORI in collaboration with Tokyo University of Marine Science and Technology, and Iwate University.

This project intended to first establishes a base in Otsuchi Bay by re-building the International Coastal Research Center (ICRC) in Otsuchi and conducting multidisciplinary and intensive ecological research in the bay and adjacent area. It investigates the ecosystems in northern part of the Sanriku coast. Restoration process of bioresources from the food chain aspect would be identified and cycling of matter from neritic to oceanic regions would be examined.

3) Factors controlling open ocean benthopelagic ecosystem dynamics

Conducted by JAMSTEC in collaboration with Tokai University

This project involves debris mapping of the bottom layer of the offing and conduct long-term monitoring of offing ecosystems, including the dynamics of the bioresources and the accumulation of chemical substances. This project employs research vessel and newly build remotely operated vehicle (ROV) to observe and obtain samples from bottom environments.

4) Data sharing and publication

Conducted by JAMSTEC

All results obtained from the research program will be made available not only to scientists but to people who are related to fisheries, local governments and the general public. Furthermore, researchers all over the world would be able to access the data through databases that will be created and maintained. Information would also be distributed through organization of symposia, publication of various articles in scientific journals, publication of popular articles in newspapers or telecast of documentaries/reports on TV.

4. Our knowledges

The followings are details of each project

Project-1 Studies on ecological succession of fishery grounds (Project leader: Akihiro Kijima, IMFS, Tohoku University)

This project has been conducted by Graduate School of Agricultural Science, Graduate School of Science, and Graduate School of Life Science of Tohoku University, School of Marine Biosciences of Kitasato University. The Project 1 aimed to comprehend the impacts and the recovery mechanisms after the GEJE catastrophe. This project was based in the Onagawa Field Center of Tohoku University, where marine observations and ecological research had been carried out before the GEJE disaster. To perform this project quickly and effectively, a partnership with the local fishery research organizations and fishery cooperative association was created. This was an attempt to scientifically investigate the impact of GEJE on the fishery grounds along the coastal areas of the southern Sanriku (south coast of Iwate Prefecture and all coast of Miyagi Prefecture) (Fig. 3) and assesses the changes of the ecosystems through the process of recovery. Thus, by revealing the mechanism of ecosystem recovery based on long-term surveys and research, this project would contribute to rebuilding of the regional industries, particularly, its fisheries.

Subject-1 Environmental monitoring in coastal areas of Miyagi Prefecture

The environmental changes after the earthquake and tsunami have been researched due to availability of ships and buoys for biological, chemical and physical data on water and sediment quality, chemical substances, and abundance and species composition of plankton and benthic animals. These data are used to understand the effects and recover mechanisms of the fishery grounds in the coastal areas of Miyagi Prefecture.

Fig. 3. Research field map of Project-1

Subject-2 Ecosystems and genetic research to conserve and restore the coastal fisheries areas in Miyagi Prefecture

Tsunami and land subsidence caused by the mega-earthquake changed the environment of the coastal rocky area. To restore the coastal ecosystem, monitoring of the dynamics and recovering processes of seaweed forest and animals was commenced. Furthermore, the genetic diversity of benthic invertebrates and demersal fishes distributed in these coastal areas are also being surveyed.

Subject-3 Researches on the coastal fisheries resources and the tidal flat fauna area in Miyagi Prefecture

Coastal sandy beach and tidal flat areas were hugely disturbed. Furthermore, subsidence and remaining debris are still obstructing the recovery of ecosystem and the fishing activity. To comprehend the status and recovery process of the coastal ecosystem, monitoring of fisheries resources, benthic animals, planktons, and fauna in the coastal shallow, tidal flat and lower river areas has been continued.

Subject-4 Aquaculture environment in the coastal water of Miyagi Prefecture and innovation of aquaculture systems

The tsunami caused by the mega-earthquake has caused great damage to cultivation facilities for fish and shell aquaculture along the Sanriku coast. Aiming towards re-building of the cultivation system, efficient production of oysters, clams, scallops fishes and growth conditions for the cultures are being investigated. Harm caused by chemical materials and the degree of pollution which is indicative of the impact of the disaster are being studied along with responses for aquaculture production.

Subject-5 Studies on the coastal environment and marine resources in the southern part of Iwate Prefecture

With an aim of assessing the impact statement of the tsunami and land subsidence, investigations of water quality as seawater properties, toxic phytoplankton, intertidal organisms, and fish larvae and juveniles as biological components in the coasts of the southern Iwate Prefecture are being conducted. Furthermore, the genetic diversity of fishery animals from the aspect of genetics of natural populations is being investigated.

Project 2. Factors controlling marine ecosystem dynamics (Project leader: Kazuhiro Kogure, Center for Earth Surface System Dynamics, AORI)

Kazuhiro KOGURE, AORI, the University of Tokyo

This project has been conducted by AORI and has the following characteristics－.

First, many scientists had carried out research on particular ecosystems or living organisms in Otsuchi bay or adjacent areas since ICRC was built in 1973 as Otsuchi Marine Research Center. Therefore, it was appropriate and necessary to use ICRC as the major base for comparative works before and after GEJE. Another aspect that needs to be considered is that during the course of c.a. 40 years of investigations, help by fishermen was indispensable for scientists and ICRC. For instance, fresh biological specimens such as salmon or turtles were available only when fishermen bring them immediately after the catch. For setting sensor buoys in the bay, fishermen offered assistance, boats and the sites for scientists. ICRC, however, was severely damaged by the tsunami and even at the end of 2015, only a part of it was rebuilt and used. Nevertheless, in addition to small laboratory space, ICRC has currently four research boats, sensors that are moored in the bay, diving equipment, and a few aquarium tanks. Many project members visit ICRC to conduct various types of research.

Second, in AORI, scientists are conducting basic research in the fields of physics, chemistry, biology, fishery and modeling. Therefore, multi-disciplinary approaches are being carried out through collaborative works among them and also together with scientists from 20 other institutions. Currently, more than 200 scientists and students from all over Japan have contributed towards this project. The knowledge thus obtained would clarify basic mechanisms of fish production in the surrounding areas of Otsuchi and would help establish the local fishing industry based on scientific information.

Third, AORI had long tradition to use and operate research vessels, Tansei Maru and Hakuho Maru, both of which belong to JAMSTEC since 2004. In January 2013, Shinsei Maru was built as a research vessel to replace Tansei Maru which retired in January 2013. The major mission of Shinsei Maru is for contributing to TEAMS or research in Tohoku area. AORI has conducted 15 cruises in Tohoku area by using Tansei Maru, Daisan Kaiyo Maru, and Shinsei Maru.

Fourth, we have tried to transfer our knowledge to local people, especially fishermen. For instance, the physicochemical data of the seawater obtained by the sensors in Otsuchi Bay are being sent to cell phones of locals and is recognized as useful and important information for fisheries. Also, meetings or symposia have been organized in Otsuchi or Iwate Prefecture. “Maillet Letter” has been published on a regular basis and distributed to schools, fishermen and locals.

Finally, the name of Otsuchi town means “big mallet” in English and “grand maillet” in French. Therefore, the nickname of this project is Projet Grand Maillet (PGM).

The scheme of Project 2 is illustrated in Fig. 4.

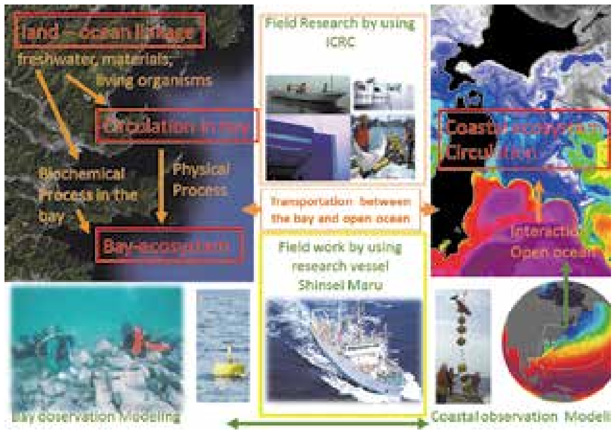


Fig. 4. General scheme of Project 2.

Subject 1: Construction of monitoring system for the coastal region, and the establishment of the marine analysis center

PI: Atsushi Tsuda, Division of Marine Life Sciences, AORI,
e-mail: tsuda@aori.u-tokyo.ac.jp

Continuous monitoring of the marine environment in Otsuchi Bay and its surrounding area would be carried out. A system to collect real time environmental information would be created. In addition, a center to employ unified high sensitive methods for analyzing diverse samples gathered during the project would be established.

Subject 2: Study on the disruption and the subsequent recovery process of the ecosystem hit by the earthquake and tsunami

PI: Tomohiko Kawamura, Coastal Ecosystem Restoration Laboratory, International, Coastal Research Center, AORI,
e-mail: kawamura@aori.u-tokyo.ac.jp

The earthquake and tsunami caused disturbance of marine ecosystems and affected a number of factors, such as the distribution, habits, and behavior of living organisms in the region. By combining the knowledge and skills of various specialists, continuous research on numerous subjects would clarify the impact of the disaster, as well as possible steps in the process towards recovery.

Subject 3: Study on material circulation process changes accompanying the earthquake
PI: Toshi Nagata, Department of Chemical Oceanography, AORI.
e-mail: nagata@aori.u-tokyo.ac.jp

Continuous nutrient supply to the Sanriku coastal region supports phytoplankton growth, which is responsible for the seafood abundance in the area. The earthquake and tsunami produced changes in landforms, causing new patterns of freshwater inflow in coastal areas, as well as alterations in ocean currents. These changes had an impact on nutrient supply mechanisms and the food chain structure. Through detailed analysis of this impact, mechanisms of maintenance and production of fishery resources would be elucidated.

Subject 4: Elucidation of the actual status and impact of land-based pollutant inflows PI: Hiroshi Ogawa, Department of Chemical Oceanography, AORI.
e-mail: hogawa@aori.u-tokyo.ac.jp

The destruction of the town caused by the earthquake and tsunami is predicted to have changed the quantity and quality of various substances that poured into the sea from the land. Furthermore, there is a possibility that some of the buildings and their contents that were swept into the sea may still remain on the bottom or within the sediment of the coastal region and release artificial substances into the water. By using highly sensitive detection technology, fate and impact of environmental pollutants would be assessed.

Subject 5: Construction of an integrated model combining ecosystem and physical processes
PI: Kiyoshi Tanaka, Coastal Ecosystem Restoration Laboratory, International Coastal Research Center, AORI,
e-mail: ktanaka@aori.u-tokyo.ac.jp

Otsuchi Bay is located along the western margin of the North Pacific in an area where the Tsugaru, Oyashio, and Kuroshio currents form a complex mixture of waters. The movement of these currents has a significant impact on the flow dynamics and the mixing process of chemicals, as well as on biological processes. The movement of these currents would be studied in conjunction with results of biological information by constructing an integrated model of the ecosystem.

Subject 6: Analysis of the chemical dynamics in water catchment areas, rivers, estuaries and coastal waters (till March 2016)
PI: Teruyuki Umita, Graduate School of Science and Engineering, Iwate University
e-mail: umita@iwate-u.ac.jp

Chemicals from the land flow into the coastal waters, which affects not only the primary production of plants, but also a variety of biological processes in the coastal area. By means of basic research of the rivers in the Sanriku area, the impact of freshwaters on the coastal ecosystem would be clarified.

Subject 7: Monitoring and modeling of river water mixing and diffusion in estuaries, brackish waters and coastal area (till March 2015)
PI: Hidekatsu Yamazaki, Graduate School of Marine Science and Technology, Tokyo University of Marine Science and Technology. e-mail: hide@kaiyodai.ac.jp

Depending on various factors, such as the quantity of the flow, temperature, and the structure of estuaries and the seabed, the river water gradually mixes with the seawater and flows to the open sea. In order to estimate the dynamics of the chemicals and their contribution to the biological production in the bay, it is important to accurately clarify the mixing and diffusion process. Thus, physical processes were modeled, making full use of the observation equipment originally developed for the project.

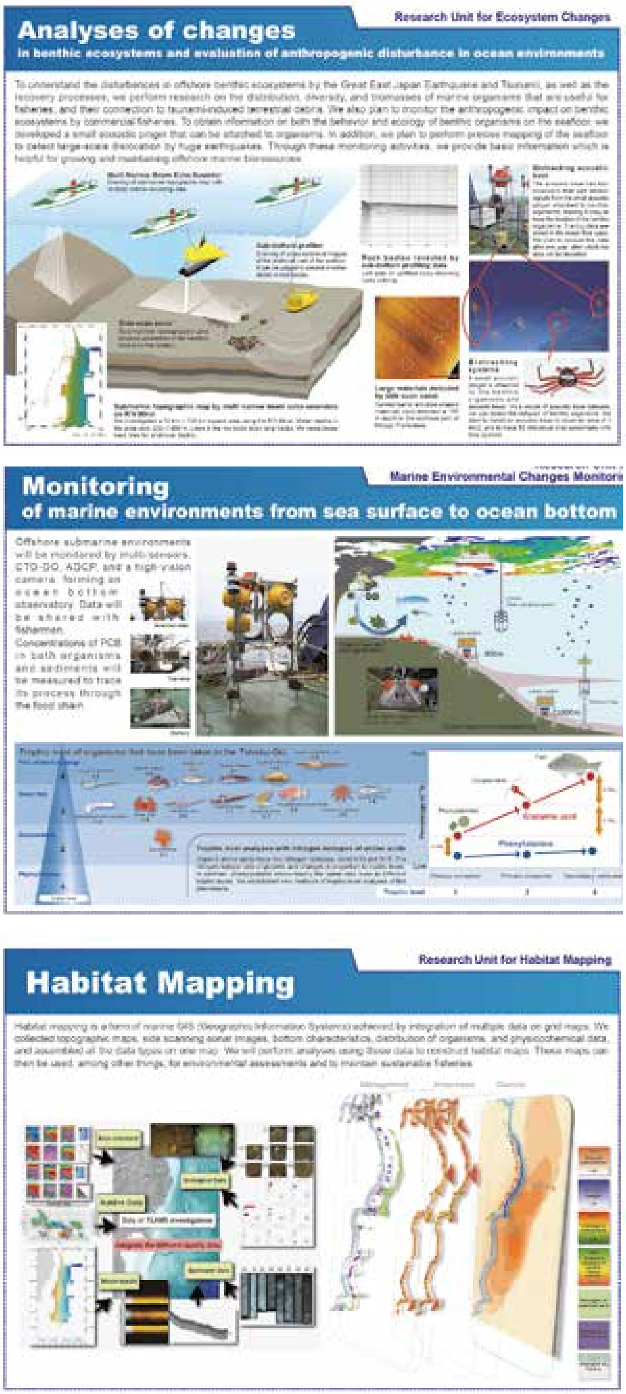
Fig. 5 At local fish market in Otsuchi town.

Project 3. Factors controlling open ocean benthopelagic ecosystem dynamics

(Project leader: Hiroshi Kitazato, JAMSTEC)

Katsunori FUJIKURA, Hiroshi KITAZATO
JAMSTEC

Monitoring and recording of restoration of marine ecosystems have been made in cooperation with citizens of Tohoku District who are damaged by earthquake and tsunamis. Scientific results will be shared with the citizens for helping towards restoration of fisheries in the area.



Theme 3 are composed of three units, analyses of changes in bottom environments and biota, monitoring of oceanographic environments and integration of whole data as habitat mapping projections. General scheme for three units are shown in Fig. 1.

This research systems and styles are so unique that we have planned to use the project as a model for monitoring disastrous marine ecosystem changes caused by huge earthquake and tsunamis in other parts of the world including south-west Japan in the near future. Some significant findings from our research are listed below.

Analyses of changes in benthic ecosystems and evaluation of environmental disturbances

Submarine topography is needed to make clear how marine debris have affectied marine ecosystems off Tohoku. We have continued to produce bathymetric maps using multi-narrow beam echo sounders installed on research vessels. Detailed bathymetric map covering 70% sea area up to the depth of 1000m has been generated (Fig. 7).

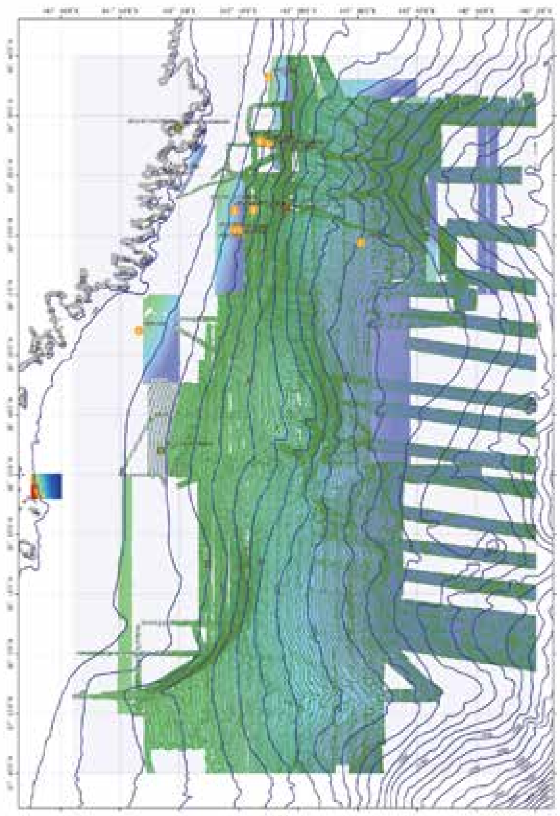


Fig. 7. Submarine topographic map off Tohoku area.

←
Fig. 6 Three research units that consist theme 3.

Monitoring of marine environmental changes

For evaluating changes in marine environments and biological features from the point of view of pollutions to ecosystems, general oceanographic observations, long-term monitoring of benthic ecosystems and sediment-water interface, biogeochemical measurements including trophic positions of animals using amino acid nitrogen isotopic values and PCB: polychlorinated biphenyl concentrations in organisms and environments are continuously being carried out.

Oceanographic measurements

Results from oceanographic observations that were carried out in March, 2015 are shown in Fig. 8. Cold water mass (Temp. ~ 3.5 ℃, salinity 33 psu) of Oyashio currents was located above 50m deep at the time of observation. In contrast, relatively warm water mass (Temp. 5.5 ℃, salinity 33.5 psu) of Tsugaru Warm Water were distributed at 150 m deep level.

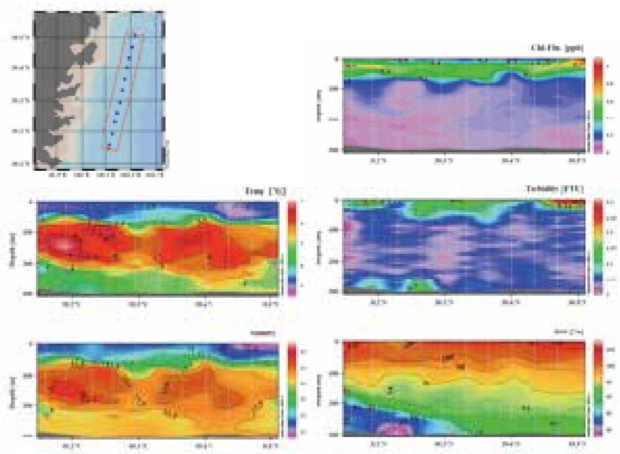


Fig. 8 Results of measurements off Otsuchi, Iwate Prefecture in March 2015.
Upper left panel: Observed station, middle left panel: temperature(℃), lower left panel: salinity.
Upper right panel: Chlorophyll (ppb), middle right panel: turbidity (FTU), lower right panel: dissolved oxygen concentration (%)

Results of oceanographic observations in 2015were compared with earlier data (Shinsei Maru KS-14-3 cruise data in March, 2014) and permanent observation line between Shiriya and Esan by Mutsu Institute, JAMSTEC. In February and March, 2014, fishery was strongly damaged due to colder and lighter saline water that occupied closer to Shimokita Peninsula. Tsushima warm current origin water flow through Tsugaru strait in regular years. In 2014, subsurface cold water originating from Japan Sea Proper water may have flown into the Pacific through the Tsugaru strait. This water can be detected up to the border areas of Aomori-Iwate prefectures.

Sea floor observatory (Lander deployment)

For monitoring benthic environmental changes, two benthic landers were deployed off Otsuchi at 300m and 998m deep. Results are shown in Fig. 9.

① Lander deployed at 300m depth

Following observations were made.

- Contour current from NNE to SSW with 0~30m sec were seen with 12 or 24 hours period. Half day or daily intervals may reflect tidal rhythm.
- Early May, 2013, bottom water rapidly changed from 8 ℃, to 2 ℃, whereas salinity decreased from 33.3 to 32.8 psu (Fig. 9). Colder water mass corresponded to coastal Oyashio or Oyashio waters. Fishermen called the water mass as **"Hiyamizu"** (= cold water).
- Bottom water turbidity changed in connection to surface spring bloom. Shallower sea floor could cause greater reflectance due to sinking particles (Fig. 9)..

② Lander deployed at 998 m depth

Following observations were made.

- Bottom surface current from NNE to SSW flowed at a rate of 0 ~ 15 m /sec. Current speed changed periodically every 12 or 24 hours. The current is induced by tidal rhythm (Fig. 9).
- A benthic nepheloid was observed on December 7, 2012. This may be strongly connected to an earthquake (M = 7.3) that occurred off Miyagi Prefecture. Series of underwater photographs hae revealed that bottom surface and benthic organisms were covered with muddy substrate, but they recovered on the following day (Fig. 9). Thus, our findings indicate that bottom disturbances could have easily taken place on the sea floor, but the benthic organisms could easily recover within a day.

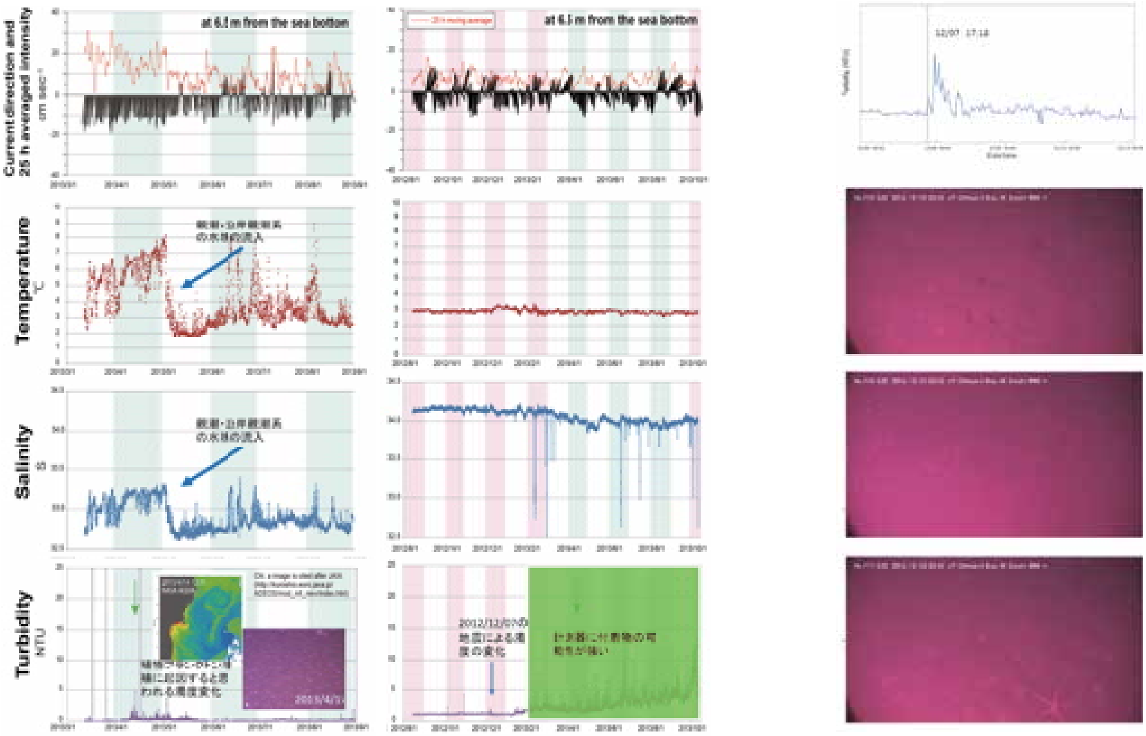


Fig. 9 Flow direction and speed, temperature, salinity and turbidity from lander measurements.
Right panel show the results from lander deployed on off Otsuchi with 300m depth（Mooring period：March 12~September 2, 2013,
Left panel show results from lander deployed at 998m（Mooring period：August 14, 2012 ~ October 14, 2013）

Habitat and ecosystem mapping

Habitat and ecosystem mapping team in TEAMS aims to determine the situation of ecosystem based on spatial data set including occurrence record of marine organisms and environmental conditions. The maps are expected to enhance comparative studies on effects of great tsunami, state of marine biodiversity, identification of ecologically important area for ecosystem resilience, and prediction of future situations.

For this purpose, the team intensively collects various data on bathymetry, geography, oceanography, seafloor classification, benthos, and tsunami-debris (Fig. 10).

Data was obtained from direct field surveys conducted by TEAMS, data archives of the institutes and contribution from other research programs. Baseline data was collected before the earthquake parallel to obtaining the data after the earthquake.

Fig. 10. Images of overlaid data. →

To visualize data and to clarify the connectivity among evidences of the impact of tsunami in these data, data (before and after the earthquake) was combined on Geographical information system (GIS).

First, data was presented by overlaying with predicted potential map of species distribution in the coastal area which had more data.

After the several cruises, compilation of deep sea data was commenced. For example, distribution of debris are compared with data from different cruises and have shown higher number of debris in the valley (Fig. 11). The data of the deep sea species distribution are being made as a preliminary map of the bottom habitat. Mosaic images were put into the 3d GIS maps for easy understanding of the three dimensional structure of the deep sea (Fig. 12). Prediction of the distribution of fishes and production of finer scaled map are the next challenging issues.

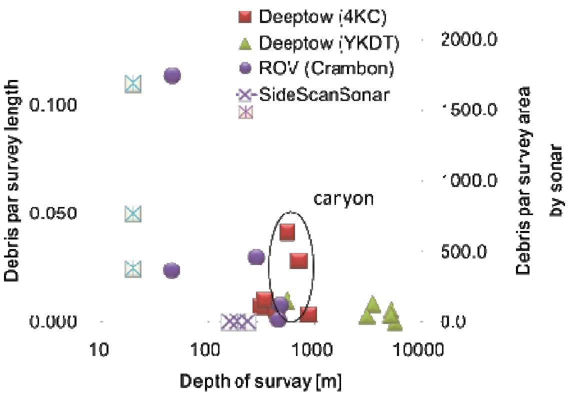


Fig. 11. Normalized number of the debris in different cruise.

Project 4. Data sharing and publication by Development and Operation of Information Systems for TEAMS (Project leader: Akira Sonoda, JAMSTEC)

For sharing information of TEAMS activities and data obtained by project researchers with TEAMS members and the public, an integrated management system for the project data management office (DMO) was constructed for TEAMS.

DMO achieved three major things for the purpose of constructing the integrated management system; (1) established a TEAMS data policy as a prerequisite for data and information publishing, (2) developed databases and information systems for data and information sharing and publishing, and (3) published those data and information via the Internet.

(1) TEAMS data policy

A data policy for TEAMS with data management task group was made, which consists of a representative member from Tohoku University, AORI and JAMSTEC that are involved in TEAMS. The details of a data policy are available on the TEAMS official website (http://www.i-teams.jp/). The major points of the policy are followings:

- ✓ All scientific information obtained by TEAMS activities would be collected, stored and opened to the public by DMO.
- ✓ The property of TEAMS data and samples belong to the institutes where the scientists investigated these data and samples.

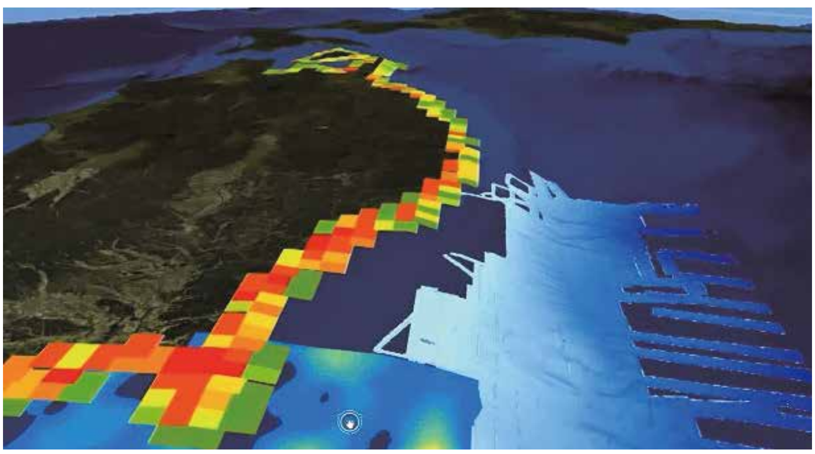


Fig. 12. Example of the 3D GIS. Habitat of little neck clam is overlaid on the topography and brittle star distribution

(2) Construction of TEAMS systems

To share:
To share information on research activities with related members, "TEAMS Members Site" was developed. This system provides members with unified management of various information, such as their research plans, measured data, reports, and other products. Those information and data archived in this system are transferred to other databases and information systems for publication.

To publish:
With respect to data and information publishing, the data catalog system for disseminating data and information of TEAMS was developed. The system is a web-based system that can operate various kinds of data and information.

Using the data catalog system, three data sites were constructed. 1) Research Information and Data Access Site (RIAS) of TEAMS that disseminate a broad range of marine scientific data collected by TEAMS activities, 2) Observation Plan and Result of TEAMS and 3) Publication and Outreach of TEAMS (Japanese only) which are accessible through the TEAMS official website (Fig.13). In addition, a new data site for videos taken by TEAMS is being constructed.

To support:
To support generating mass occurrence records of marine species obtained in ecosystem research in TEAMS, "Biological Observation Record Archive System (BORAS)" has been developed (Fig. 14). Any individuals and/or groups in TEAMS can store and manage their own biological observation records in BORAS and also

Fig. 14. Screenshot of the page for thumbnail list of records in "BORAS".

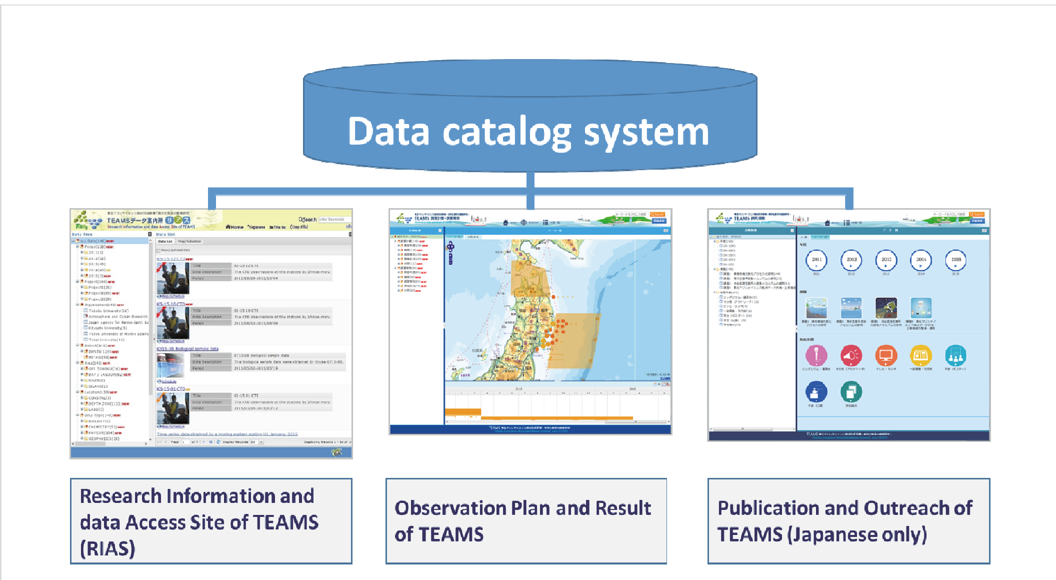


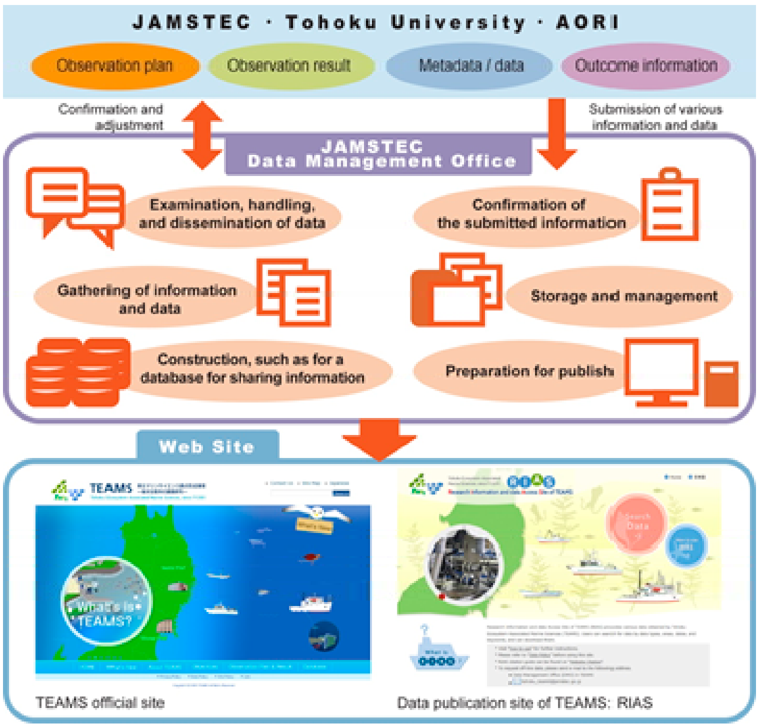
Fig. 13. Image of data publishing using the data catalog system.

share those records with the other BORAS members. This system facilitates cooperation among TEAMS members and supports generating biological occurrence records in a standardized format.

Furthermore, a new data-providing system is being developed that would focus on a large environmental data such as water temperature, salinity and others, to support researchers.

(3) Publication of TEAMS data and information

Under the data policy of TEAMS, 136 Observation plans, 80 Observation results, and 138 Data have been collected by December 10th 2015.



By using the systems, the information of Observation Plans and Results were shared in an online data catalog "TEAMS Observation Plan & Result" on the TEAMS official website. Data is available in an online database "Research Information and data Access Site of TEAMS (RIAS)" (Fig. 15).TEAMS activities information is announced at TEAMS official site.

Also, information on related sites such as TEAMS website in Tohoku University, AORI and JAMSTEC, is collected automatically, and is announced at the official site of TEAMS.

- TEAMS official site URL: http://www.i-teams.jp/
- Research Information and Data Access Site of TEAMS (RIAS) URL: http://www.i-teams.jp/rias/

Fig.15. Image of the workflow for information and data

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6. List of contributed papers

6-1. RESEARCH VESSEL

1. Kogure K.
   Scientific cruises using research vessels

6-2. PHYSICAL PROCESSES

2. Tanaka K., Komatsu K., Itoh S., Yanagimoto D., Ishizu M., Hasumi H., Sakamoto T.T., Urakawa L.S. and Michida Y.
   High-resolution hydrographic observation with local communities in the Sanriku coastal seas, Japan
3. Ishizu M., Itoh S., Tanaka K. and Komatsu K.
   Mooring observations of ocean circulation in Otsuchi Bay, Japan influenced by open ocean conditions
4. Yanagimoto D., Tanaka K., Fujio S., Nishigaki H. and Ishizu M.
   Observation of spatial distribution of near-bottom current speed on the continental shelf off Sanriku
5. Sakamoto T.T., Urakawa L.S., Hasumi H. and Tanaka K.
   Numerical simulation of climatological circulation in Otsuchi Bay
6. Urakawa L.S., Hasumi H., Kurogi M., Sakamoto T.T. and Tanaka K.
   For numerical simulation of Otsuchi Bay; tides in our nested-grid model
7. Takahashi D., Gomi Y. and Kijima A.
   Semidiurnal tidal current in Onagawa fishery port, Japan, after the 2011 off the Pacific coast of Tohoku Earthquake

6-3. CHEMICAL PROCESSES

8. Ogawa H., Suzuki T., Mizukawa K., Sugihara N., Takada H.
   Effluent and transportation of terrigenous organic matter to Otsuchi Bay and its offshore area by the huge tsunami in 2011
9. Lu C-J., Benner R., Fichot C.G., Fukuda H., Yamashita Y. and Ogawa H.
   The fate of terrigenous dissolved organic matter in Otsuchi Bay, Japan: The implication from a decomposition experiment
10. Mashio Suzuki A., Obata H., Fukuda H. and Ogawa H.
    Distributions and biogeochemical cycles of platinum in Otsuchi Bay after the tsunami in 2011
11. Ohkouchi N., Shibata H., Chikaraishi Y., Nomaki H., Ogawa N.O., Nagata T., Goto T., Fujikura K. and Kitazato H.
    A monitoring result of polychlorinated biphenyls (PCBs) in deep-sea organisms and sediments off Tohoku during 2012-2014
12. Mizukawa K., Hirai Y., Takada H., Sugihara N.M., Shirai K. and Ogawa H.
    Spatial distribution and temporal trend of anthropogenic organic compounds derived from the 2011 East Japan Earthquake
13. Sugihara N.M.., Shirai K., Sano Y. and Ogawa H.
    Mussel shell recorded the coastal environmental change induced by the huge Tsunami
14. Yamaguchi T., Seki A., Nanba T., Yamauchi A., Kaneko K., Nakano T., Sato M. and Ochiai Y.
    Chemical substances from marine sediments in Onagawa Bay after Great East Japan Earthquake
15. Yamada T., Minoura K., Hirano S., Sugihara S., Kato H., Sato S., Nishi H. and Takashima R.
    Distribution of radiocesium released by the 2011 Fukushima nucleear accident in the coastal region of Sendai Bay

6-4. MATERIAL CYCLES

16. Fukuda H., Katayama R., Yang Y., Takasu H., Nishibe Y., Tsuda A. and Nagata T.
    Nutrient status of Otsuchi Bay (northeastern Japan) after Great East Japan Earthquake
17. Yamada Y., Kaga S., Kaga Y., Naiki K. and Watanabe S.
    How did seawater quality in Ofunato Bay change after the 2011 Earthquake?
18. Gomi Y., Takahashi D. and Kijima A.
    Marine environment in the bays of the northern Miyagi prefecture –comparision among Shizugawa bay, Ogatsu bay and Onagawa bay-

6-5. BIOLOGICAL PROCESSES

-rocky habitats-

19. Kawamura T., Hayakawa J. and Takami H.
    Changes in rocky shore ecosystems on Sanriku Coast damaged by the Great East Japan Earthquake in 2011
20. Hirose M. and Kawamura T.
    Sessile organisms in Otsuchi Bay and Matsushima Bay after the Great East Japan Earthquake and Tsunami
21. Noda T., Iwasaki A. and Fukaya K.
    Rocky intertidal zonation: impacts and recovery from the megaquake

-tidal flats and estuary-

22. Kondoh T. and Sato-Okoshi W.
    Recoveries of the tidal flat ecosystems after the 2011 earthquake and tsunami
23. Okoshi K.
    Short-term and long-term effects of the 2011 earthquake on intertidal mollusks
24. Itoh H. and Kojima S.
    The genetic disturbance caused by the mega-tsunami on a coastal species
25. Ito K., Yoshida H., Morioka Y., Katayama A., Takahashi D., Shoji M., Sasaki K. and Katayama S.
    Distribution of the Manila clam, Ruditapes philippinarum, and physical environmental conditions in the Natori River estuary in northeastern Japan after the Great Tsunami
26. Kawakami T., Hata M. and Otake T.
    The immediate impact of the tsunami on ayu Plecoglossus altivelis altivelis population in Sanriku region

-soft bottom habitats-

27. Komatsu T., Otaki T., Sawayama S., Asada M., Gonzalovo S., Sakamoto S., Terauchi G., Tsujimoto R. and Sasa S.
    Impact of the huge tsunami on 11 March 2011 to

seagrass and seaweed beds in Sanriku Coast, Japan

28. Tanaka N., Tamaki H., Muraoka D., Tokuoka M., Sakamoto S., Komatsu T. and Nakaoka M.
    Impact of the Great East Japan Earthquake and Tsunami on the abundance and genetic diversity of seagrass beds along the northeastern coast of Japan
29. Seike K.
    Succession of benthic animals and bioturbation after the tsunami disturbance
30. Tanaka K., Yokoyama Y., Sakamoto I., Nemoto K., Fujimaki M., Kasaya T. and Fujiwara Y.
    Soft bottom benthos in nearshore areas of Iwate Prefecture, Japan
31. Nomaki H., Kitahashi T., Arai K., Nunoura T., Toyofuku T., Mochizuki T., Juliarni, Tanaka G., Sugime S., Suga H., Yokoyama Y., Sakamoto I., Wakita M., Tasumi E., Shigeno S., Oguri K., Kasaya T., Fujikura K. and Watanabe S.
    Changes in sediment geochemistry and the distribution of benthic organisms at bathyal depths after the 2011 off the Pacific coast of Tohoku Earthquake

-planktons-

32. Nishibe Y., Tachibana A. and Tsuda A.
    Zooplankton community in Otsuchi Bay, northeastern Japan after the 2011 Tohoku earthquake tsunami
33. Tachibana A., Nishibe Y. and Tsuda A.
    Seasonal change of phytoplankton community in Otsuchi Bay, northeastern Japan after the 2011 off the Pacific coast of Tohoku Earthquake and tsunami

-biologging-

34. Sato K., Narazaki T., Fukuoka T. and Kinoshita C.
    Seasonal migration of sea turtles to a temperate habitat in Sanriku Coastal Area

-microbes-

35. Fujimura R., Kaneko R. and Kogure K.
    Identification of active bacterial community in the temperate coastal region of Sanriku area
36. Kaneko R., Hamasaki K. and Kogure K.
    Bacterial communities in the coastal waters of Onagawa Bay and Otsuchi Bay of the Sanriku coastal area, Japan
37. Yang Y., Fukuda H. and Nagata T.
    Possible transient impacts of the 2011 Earthquake on the microbial system in Otsuchi Bay
38. Hiraoka S., Machiyama A., Ijichi M., Inoue K., Oshima K., Hattori M., Yoshizawa S., Kogure K. and Iwasaki W.
    Genomic and metagenomic analysis of microbes in a soil environment affected by the 2011 Great East Japan Earthquake Tsunami

6-6. FISHERIES

39. Nobata S., Kitagawa T., Aoyama J., Kusakabe M., Takei Y. and Hyodo S.
    Impact of the Tsunami on homing of chum salmon, Oncorhynchus keta, in Otsuchi Bay
40. Qin Y., Ogawa G., Shimizu Y., Yamane K. and Kaeriyama M.
    Early ocean life history of juvenile chum salmon Oncorhynchus keta populations in the Iwate coastal ecosystem after the Great Tohoku Earthquake and Tsunami
41. Kusakabe M., Nobata S., Saito K., Iki A., Ando M., Wong M., Takagi W., Imaseki I., Ogawa S., Shimada T., Takei Y. and Hyodo S.
    Changes in the plasma sex steroid levels of chum salmon returning to the Otsuchi Bay during the home migration period
42. Tamada S., Hayashizaki K. and Goto T.
    Feeding environment of juvenile Japanese flounder Paralichthys olivaceus along the northern Iwate coast
43. Minegishi Y., Ikeda M., Kurita Y., Togashi H., Nakane Y. and Kijima A.
    Evaluation of the genetic diversity of the marbled flounder in Sendai Bay
44. Sasaki R., Kaneko K. and Hara M.
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45. Osada M., Nagasawa K., Takahashi D. and Takahashi G.K.
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46. Nagasawa K., Oouchi H., Itoh N., Takahashi G.K. and Osada M.
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47. Kurita Y., Hashimoto N. and Kijima A.
    A novel method for DNA extraction from bivalves
48. Agatsuma Y., Takagi S., Murata Y., Inomara E., Horikoshi A., Endo H. and Aoki N.M.
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49. Sakamoto I., Yokoyama Y., Yagi M., Inoue T., Iijima S., Nkada Y., Fujimaki M., Tanaka K., Nemoto K., Kasaya T. and Fujiwara Y.
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50. Yokoyama Y., Sakamoto I., Yagi M., Inoue T., Nakada Y., Fujimaki M. and Nemoto K.
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51. Yagi M., Sakamoto I., Yokoyama Y., Iijima S., Nemoto K., Fujimaki M., Fujiwara Y. and Kasaya T.
    Changes of submarine topography effect caused by 3.11 earthquakes at Toni bay
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    Changes in abundance and composition of anthropogenic marine debris on the continental slope off the Pacific coast of northern Japan, after the March 2011 Tohoku earthquake

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    Seasonal changes and an earthquake induced disturbance recorded by deep-sea stations in continental slope, off Otsuchi Bay, Northeastern Japan
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    Use of bottom image mapping by a new underwater camera system, and application of 3D mosaicking to observe the spatial distribution of benthic organisms off the coast of Sanriku.
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58. Hosono T., Yamuchi T., Kaneko J., Hiromatsu M., Iseto T., Ichiyanagi M., Ishiguro S., Irei K., Suzuki H., Kayo M., Wakata C., Saito H., Hishiki M., Hase H., Hanafusa Y. and Sonoda A.
    TEAMS database and information publishing
59. Kayo M., Suzuki H., Ichiyanagi M., Kaneko J., Hishiki M., Hase H., Saito H., Hanafusa Y. and Sonoda A.
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60. Yamauchi T., Suzuki H., Hosono T., Iseto T., Hishiki M., Saito H., Hase H., Hanafusa Y. and Sonoda A.
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Scientific cruises using research vessels

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Key words: Shinsei Maru, Tansei Maru, Daisan Kaiyo Maru, Research Vessel

【Background】

Many types of scientific approaches and platforms are required for the research conducted in Tohoku Ecosystem-Associated Marine Sciences (TEAMS). In small bays or coastal environments, moored monitoring systems, small boats, diving or direct sampling from the shores are effective ways. In order to clarify the oceanographic conditions in Tohoku area (approximately 500km long), however, scientific cruises using research vessel that can cover whole area are indispensable.

Since 2004, Atmosphere and Ocean Research Institute, the University of Tokyo (AORI) and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) started the joint usage system for two research vessels; Tansei Maru (commissioned in 1982, 610 gross tons, 11 scientists can be accommodated) and Hokuho Maru (commissioned in 1989, 3991 gross tons, 35 scientists can be accommodated). Both had cruises for the research after Great East Japan Earthquake in March 2011. Because Tansei Maru started show mechanical problems due to long-term usages, the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) raised a fund for new research vessel. In 2012, MEXT started to construct a new research vessel as a part of TEAMS.

Fig. 1 R/V Tansei Maru in Otsuchi Bay (photo taken by Kiyoshi Tanaka)

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R/V Shinsei Maru was commissioned in December 2013 and has been employed for the research in Tohoku Area. She belongs to JAMSTEC and serves as a joint usage vessel with AORI, just like Tansei Maru. Tansei Maru retired in January 2013, sold to a company, renamed as Daisan Kaiyo Maru and used for several cruises in Tohoku area in 2013.

Fig. 2. Left: R/V Shinsei Maru. Right: Research Boat Yayoi (ICRC, 12 tons). Photo taken in Sept. 2015 in Otsuchi Bay.

R/V Shinsei Maru has 1629 gross tons, and can accommodate 26 crew members and 15 scientists. She adopted the azimuth thrusters and a dynamic positioning system so that the maneuverability and fixed-point retention capacity are extremely high. Also, micrometric and real-time research on living organisms and sea bottoms can be conducted by use of massive acoustic equipment including a multi-beam echo-sounder for deep and shallow water, a quantitative eco-sounder, an all-round scanning sonar, a sub-bottom profiler and a transducer for sensor positioning of ocean floor crustal deformation.

【Aim】

In order to observe the long-term change or trend in marine environments of Tohoku area after Great East Japan Earthquake, regular base research cruises in the area at the fixed sampling points with consistent methods are required. We have organized cruises by mainly using R/V Shinsei Maru since 2012.

【What we did】

The cruise plans for R/V Shinsei Maru are set by open-application and evaluation at AORI every year. We have tried to have four cruises in Tohoku area every year. However, recent shortage of grant for vessels makes it difficult to cover cruises enough to support all the requested days. The following is the cruise by conducted. First four cruises were by R/V Tansei Maru, next two by Daisan Kaiyo Maru and the rest were by Shinsei Maru.

Cruise	Period	Year	PI
KT-12-6	28 Apr‐3 May	2012	Tsuda
KT-12-20	7-12 Aug	2012	Nagata
KT-12-27	15-21 Oct	2012	Kogure
KT-13-2	19-25 Jan	2013	Hamasaki
KK-13-1	24 June-5 July	2013	Kogure
KK-13-6	14-21 Sept	2013	Kogure
KS-13-1	8-16 Dec	2013	Kogure
KS-14-2	12-19 Mar	2014	Kogure
KS-14-4	14-21 April	2014	Kogure
KS-14-14	9-15 Aug	2014	Nagata
KS-14-19	9-14 Oct	2014	Seike
KS-15-1	5-12 Mar	2015	Kogure
KS-15-10	2-9 Aug	2015	Kogure
KS-15-12	29Sept-4Oct	2015	Kogure
KS-16-1	16-22 Mar	2016	Kogure

Fig. 3 shows an example of cruise route (KT-12-06 by R/V Tansei Maru). Stations OT4-6 locate east of Otsuchi Bay and ON4-8 locate east of Onagawa Bay.

For each cruise, basically followings have been measured and analyzed, although there have been some variations depending on the schedule and participants on board.

1. Temperature, Salinity, Current speed, Acoustic Doppler Current Profiler (ADCP)
2. Nutrients, Chlorophyll a, Pigments analyses by HPLC
3. Dissolved organic carbon (DOC), Particulate organic carbon (POC)
4. Primary productivity, Nitrogen uptake rate
5. Biomass and community structure of prokaryotes, zooplankton, microzooplankton meiobenthos.
6. Organic pollutants and heavy metals in sediments

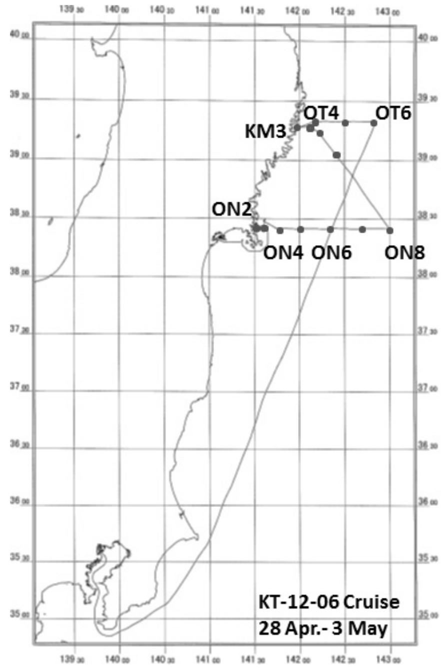

Fig. 3. Cruise route of KT-12-06 cruise

After analyses some data have been presented at various meetings, shown in scientific papers and deposited in data base.

【Conclusion】

Research cruises in Tohoku are have been conducted regularly mainly by R/V Shinsei Maru. Huge data sets are now accumulating and available through database. To monitor changes of the ecosystems after the earthquake and tsunami in 2011, continuous researches based on regular cruises are scheduled in future.

【Further readings and information】

The information of R/V Shisei Maru is available at the follwoig site;

http://www.jamstec.go.jp/e/about/equipment/ships/shinseimaru.html

The information on the utilization of R/V Shinsei Maru is available at the following site:

http://www.aori.u-tokyo.ac.jp/english/coop/index.html

Some information of the cruise data are available at the following sites:

http://cesd.aori.u-tokyo.ac.jp/cesddb/index2_en.html

http://www.i-teams.jp/catalog/rias/e/index.html

High-resolution hydrographic observation with local communities in the Sariku coastal seas, Japan

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Key words: Stratified currents, High-frequency variability, Tide, Hydrographic observation

【Background】

A variety of seaweeds and shellfish are farmed in the Sanriku coastal seas such as Otsuchi Bay, and the farming is characterized by a non-feeding type. The Sanriku coastal seas, which are located in the northeastern part of Japan, face the North Pacific and exchange a large amount of seawater with the open ocean.

【Aim】

An aim of the present study is to provide clear images of stratified current systems (baroclinic circulation) extending over the bay together with the associated intrusion of bottom water (lower-layer water) from outside the bay.

The other aim is to find ways to solve social problems simultaneously and synergistically together with local communities. This is because the hydrographic observation over the inshore fishery areas cannot be made without support from fishermen and their cooperative associations. At the same time, there are many fishery problems that cannot be solved without academic approaches; for example, the physical oceanography is needed to reveal the seawater circulation that conveys nutrients into the “non-feeding” sea farming areas.

【What we found】

A large amount of hydrographic data were collected to successfully provide clear images of the seawater circulation in the Sanriku coastal seas: During summer, for example, stratified currents (baroclinic circulation) with near-tidal frequencies, the flow speeds of which are greater than 0.1 m/s, extend over the greater part of the bay (Fig. 1). During winter, on the other hand, the currents are considerably weakened, because the stratification breaks down.

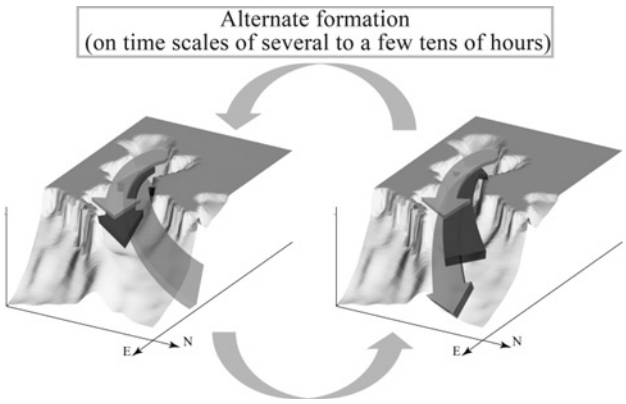

Fig. 1. Schematic views of the stratified currents in Otsuchi Bay during summer. The current system has a three-layer structure consisting of a lower-layer flow (bottom), an upper-layer flow (middle), and a surface outflow of river water (top). The direction of the lower-layer flow (inflow into and outflow from the bay) is opposite to that of the upper-layer flow. The inflow and outflow alternate on time scales of several to a few tens of hours, and the flow directions are sometimes related to the tidal ones, although the relationship is not applied persistently. The surface outflow originates in the innermost part of the bay, where fresh, buoyant waters are discharged from rivers.

Moreover, we have built a WEB site (Fig. 2) that distributes real-time-monitored marine environmental data, such as water temperature, wave height, salinity, concentration of nitrate, and meteorological conditions. The marine environmental information distributed by this system has been widely viewed and been practically utilized by the local communities including fishermen, because, for example, growth of the seaweeds and the shellfish depends greatly on the water temperature.

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Furthermore, we have held local meetings in rural fishing villages. Direct exchanges of marine information between the researchers and fishermen are very useful not only for the fishery, but also for the development of the oceanography, because the fishermen know the sea very well.

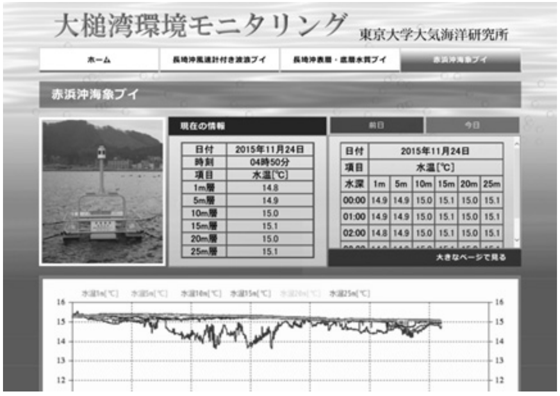

Fig. 2. Water temperature data distributed through the WEB site.

Fig. 3. Local meeting in a rural fishing village.

【Conclusion】

1. Clear images of the seawater circulation in the Sanriku coastal seas were obtained (e.g., Fig. 1).
2. The WEB site (e.g., Fig. 2) that distributes real-time-monitored marine environmental data, has been built. It has been widely viewed, and has been practically utilized by the local communities including fishermen.
3. Local meetings (e.g., Fig. 3) have been held in rural fishing villages to directly exchange marine information between the researchers and fishermen.

【How we investigated】

We made high-resolution hydrographic observation in the Sanriku coastal seas, especially in Otsuchi Bay, using a ship-mounted acoustic Doppler current profiler (ADCP) and a conductivity-temperature-depth profiler (CTD profiler, Fig. 4). Moreover, a variety of monitoring instruments, such as current profilers, thermometers, wave sensor, and so on, have been deployed in the bay (Fig. 5).

Fig. 4. Measurement of CTD profile.

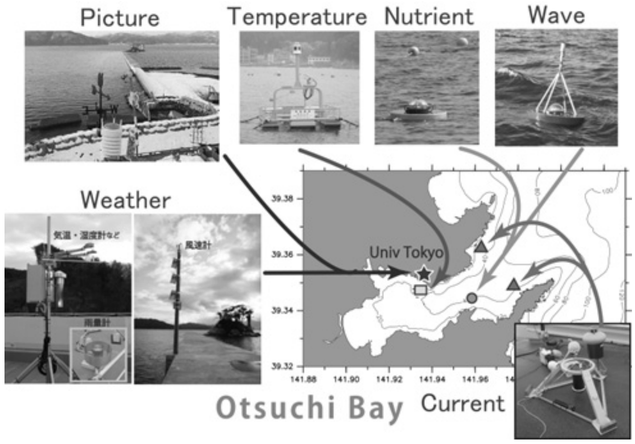

Fig. 5. Monitoring instruments in Otsuchi Bay.

Furthermore, oceanic observations were also conducted outside the bays, using a research vessel.

【Further readings and information】

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What happened to the marine environments after Great East Japan Earthquake?
Proceedings of the International Conference, March 2016

Mooring observations of ocean circulation in Otsuchi Bay, Japan influenced by open ocean conditions

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Key words: Otsuchi Bay, Tsugaru Warm Current, Oyashio, Water intrusion

【Background and Aim】

The Sanriku Coast (Fig.1: blue shaded area), Japan is a ria coast area affected by three major currents: the Tsugaru Warm Current (TWC) from the Sea of Japan, the cold Oyashio Current (OY) from the subarctic North Pacific, and the Kuroshio Current from the subtropical North Pacific.

Otsuchi Bay is a bay along the Sanriku Coast. The bay's ecosystem and fishing industry are influenced by open ocean conditions outside of the bay, especially due to the intrusion of water. The circulation pattern is also influenced by open ocean conditions, but the details remain poorly understood, particularly how and when the different waters intrude into the bay, because of sporadic observations.

Fig. 1 Map of Japan showing the location of the study site and the three major currents.

Motivated by the important influence of the open ocean on Otsuchi Bay, we conducted current mooring and hydrographic observations from September 2012 to May 2014.

【Observation System】

Two current mooring systems with bottom tripods were deployed at the mouth of the bay (Sts. N and O in Fig. 2). An acoustic Doppler current profiler (ADCP) was mounted in the center of each bottom tripod (Fig. 3). Two conductivity–temperature (CT) sensors were used to obtain temperature and salinity data in the surface and bottom waters. Hydrographic observations were carried out several times along latitudinal and longitudinal transects across the bay using a CTD profiler (Fig. 2).

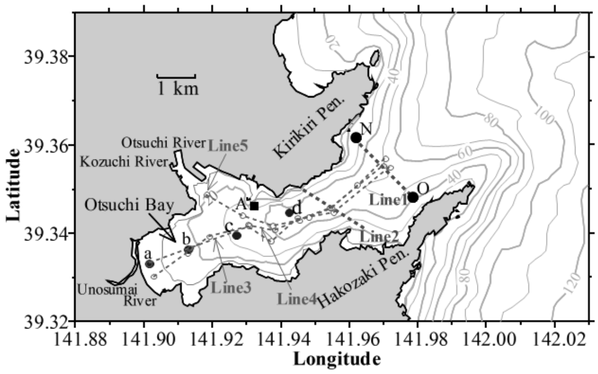

Fig. 2 Mooring stations of the seabed system (Sts. N and O). Lines 1–5, and Sts. a-d indicate shipboard CTD observation lines and stations, respectively. The square indicates Point A, where the mooring temperature observations were conducted.

Fig. 3 Photograph of the mooring current system used in our observation system.

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【What We Found】

Our observations revealed clear seasonal differences in the current patterns at the mouth of the bay. Mean inflow in the northern part of the bay and outflow in the southern part were enhanced during summer and early autumn. The mean current structure strengthened with depth. The most prominent water supply in summer and early autumn was the typical TWC water (Hanawa and Mitsudera, 1987). In winter and early spring, the inflow/outflow pattern weakened and an overturning circulation was basically detected with the less saline TWC water, (hereafter mTWC). The water property occasionally changed to OY water during the spring season (Fig. 4). The associating circulation patterns differed when the OY water intruded.

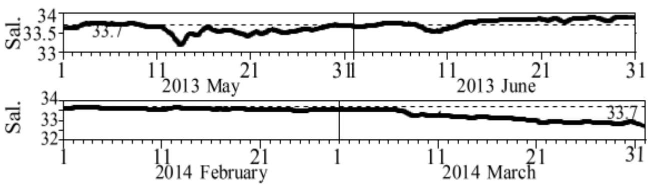

Fig. 4 Time series of salinity during low-salinity intrusions at St. O (OY intrusions).

Two dominant intrusions of OY water were detected in May 2013 and March-April 2014 (Fig. 4). The first intrusion continued for several days from 12 May 2013 (Fig. 4), but the second event lasted for more than 1.5 months from 7 March 2014 until we recovered the instrument. Satellite images captured the ocean condition that the cold water, corresponding to the OY current, approached to the Sanriku coast, and the OY water covered those regions.

Surface currents were not measured directly due to the mechanical performance of the ADCPs. However, the water on the southern side of the bay was generally cooler and less saline than that on the northern side. Therefore, a counterclockwise circulation pattern is likely prominent throughout the year, influenced by Coriolis forces (Fig. 5).

Based on our observations and on previous studies (Otobe et al., 2009), the schematic representation of circulation patterns and associating condition of the TWC and OY current are proposed as seen in Fig. 5.

The details of these circulation patterns are described by Ishizu et al. (under review). Our future study will be compared with the results of numerical experiments (Sakamoto et al., 2015) in order to gain a deeper understanding of the physical mechanisms driving circulation in the bay.

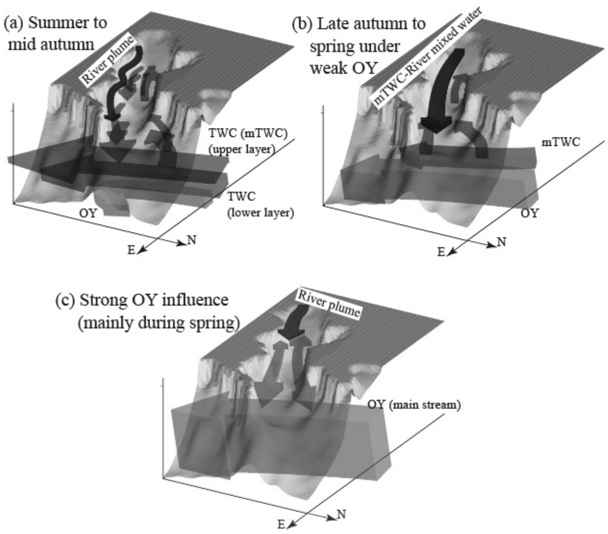

Fig. 5 Schematic representation of the circulation patterns in Otsuchi Bay and associated conditions of the TWC and OY.

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What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Observation of spatial distribution of near-bottom current speed on the continental shelf off Sanriku

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Key words: bottom boundary current, current measurement, continental shelf, Otsuchi Bay

【Background】

The giant tsunami caused by the earthquake on March 11 heavily changed marine environments in Otsuchi Bay, a ria bay in Sanriku coast. Clarification of water exchange between outer and coastal oceans is very helpful for reconstruction of aquaculture industry based on the marine environments. Bottom boundary layer on the continental shelf is thought to play an important role in the water exchange across the front between outer and coastal waters. Offshore bottom boundary current is thought to be caused by bottom friction beneath southward coastal currents such as Oyashio and Tsugaru Current (Figure 1). On the other hand, massive cold water intrusion, which is thought to originate in the bottom layer over the shelf, often occurs in Otsuchi Bay. About near-bottom current on the shelf, it is not known; how the deep outer water runs aground the shelf break and comes inshore, whether the bottom boundary current interact with the cold water intrusion or not and how if so, and so on.

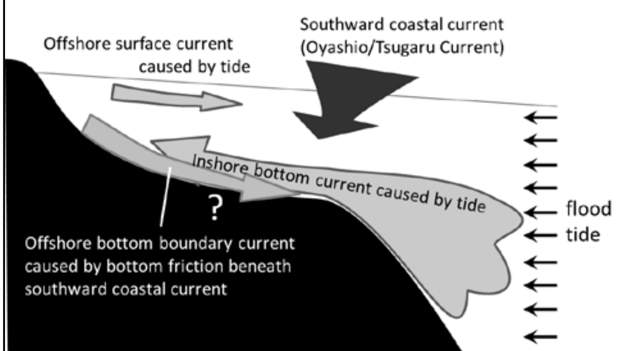

Figure 1. A supposed schematic of current on the continental shelf off Sanriku Coast at flood tide period (redraw of a figure by K. Tanaka).

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【Aim】

We aim to establish the method of direct, wide-area measurement of near-bottom current within 10-m range above the seafloor and to grasp the spatial distribution of near-bottom current speed and its temporal variation on the continental shelf off Otsuchi Bay.

【How we investigated】

Our target is the near-bottom current within a range where current speed cannot be measured by any generally-used shipboard Acoustic Doppler Current Profiler (ADCP) (see “Difficulty in measuring bottom current by ADCP”). We mount an 500-kHz ADCP (Sontek ADP 500 manufactured by Xylem) on a subsurface towfish “V-fin” (Photo 1), and make it close to the seafloor. Its pressure rating is 500 m and nominal measurement range of current profile is 70-120 m.

Because V-fin is towed with just wire rope, we cannot monitor the depth of ADCP in real time. We adopted a very compact telemetry system of Vemco, Canada, which is generally used in bio-logging field. A transmitter equipped with pressure sensor with a

Photo 1. V-fin on the board of R/V Yayoi, off Otsuchi Bay on 30 July 2015.

total weight of about 20g can be tied to a shackle connecting V-fin to wire rope.

On 30 July 2015, we boarded R/V Yayoi (12 ton, 20 persons), a vessel of International Coastal Research Center in Atmosphere and Ocean Research Institute, and towed V-fin at about 50-m depth. In order to monitor the telemetry data from the transmitter, we tied a compact hydrophone to an about two-meter long pole fixed to the left side of the ship. We observed near-bottom current for about 2 nautical miles along 100-m isobaths off Otsuchi Bay four times: 09:05 – 10:07 (observation line L1), 10:25 – 10:59 (L2), 11:06 – 11:40 (L3), and 13:47 – 14:19 (L4). All these four lines were done during flood tide which was measured at Kamaishi and Miyako from 9:00 to 16:00.

【What we found】

We succeeded in measuring near-bottom current within 10-m range above the seafloor by using V-fin mounting an ADCP. We found the transition of the near-bottom current from the start and the end of flood tide. Cross-shelf currents are dominant especially in the middle to the last half period of flood tide (L3 and L4 in Figure 2) while northward along-shelf current is dominant except for both ends of the lines in the earlier period (L1 and L2). These do not occur neither with in-phase or opposed-phase with the tide. Complex tidal current structure is suggested on the continental shelf off Otsuchi Bay. We need to pile up current data by further V-fin surveys in various conditions such as ebb tide and winter time.

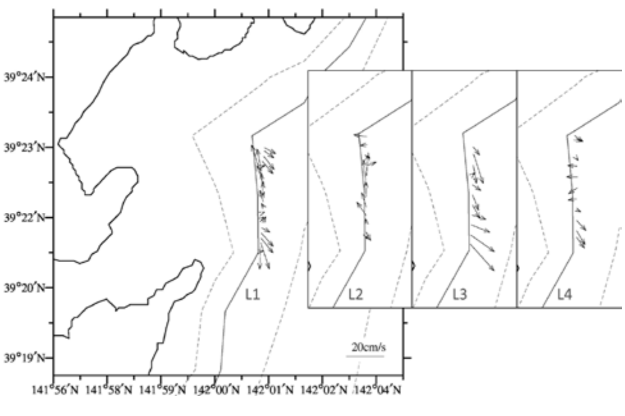

Figure 2. Current velocity distribution at 7-m height above the seafloor along the four observation lines L1 – L4 off Otsuchi Bay through the period of flood tide. Isobaths are shown by solid line for 100-m depth and broken lines for 80-m, 120-m, and 140-m depth.

【Further readings and information】

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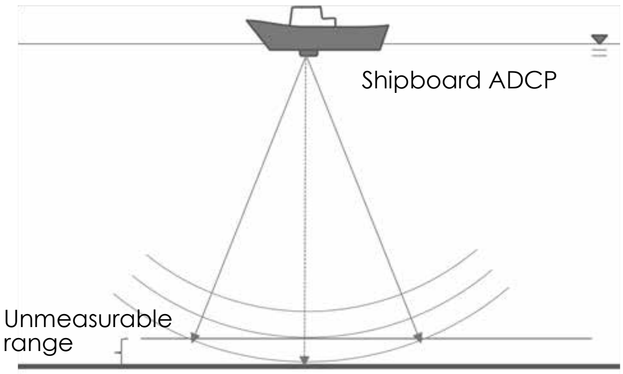
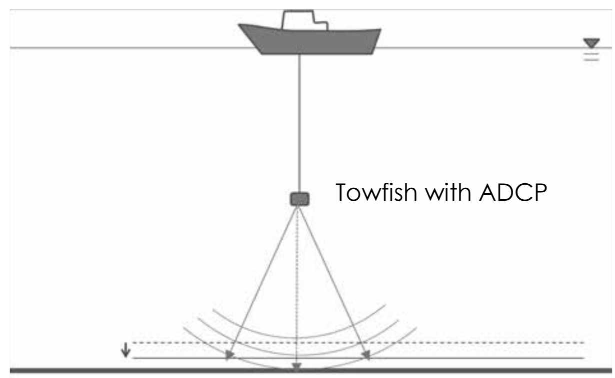
Difficulty in measuring bottom current by ADCP

For investigating current distribution in a wide area, shipboard ADCPs are suitable generally. However, ADCPs have three or four transducers which emit sound beams tilting at 10-20 degrees from vertical direction with side lobes. Even if downward beams reach the bottom, we cannot measure currents precisely within about 10% range from the seafloor to the instrument due to reflection of the side lobes. That is, shipboard ADCPs cannot measure currents within 10-m range above the seafloor at 100-m depth area for example.



So, we lower the ADCP by using a towed fish in order to make it close to the seafloor and diminish the unmeasurable range.



What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Numerical simulation of Otsuchi Bay; Cold water intrusion into the bay

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Key word: nested-grid modeling

【Background】

Huge tsunamis, caused by the 2011 off the Pacific coast of Tohoku earthquake, totally endamaged the marine ecosystem along the Sanriku ria coastal area. In order to know the ecosystem after the disaster, not only the in-situ observations but also numerical simulations are effective because numerical simulations has a potential to interpolate the spatiotemporally sparse observations.

【Aim】

Here, it is introduced how the numerical simulation in Otsuchi Bay, the Sanriku ria coast of Japan, is conducting, and some results. Especially, events of cold water intrusion into the bay are dealt here, because aquacultures in the bay are sometimes damaged by those events.

【How we investigated】

The size of Otsuchi Bay is about 8 km x 2 km. The environment in the bay is influenced by the water from the North Pacific and rivers. To represent these effects, the grid size of less than 100 m is desirable for the model. However, it is unfeasible to divide the huge ocean, the North Pacific, into less than 100 m mesh and simulate for a few years even using a state-of-the-art computing system. For solving this problem, a "nested-grid ocean model" is adopted for the present study (see the column).

【What we found】

In Otsuchi Bay, the seawater is usually composed of mixtures of the fresh river water and saline/warmer oceanic water that is so-called Tsugaru Warm Water. Sometimes it is observed that less-saline/colder oceanic water, so-called Oyashio Water, intrudes into the bay. When the Oyashio Water approaches to the Sanriku coast (Fig. 1), a cold water directly flows into

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Nested-grid system

To solve the ocean (in common with the atmosphere, the sea ice, the gracier etc.) numerically, one of the ways to divide them is to make a grid system according to the latitude-longitude coordinate. To do this, a selection of the grid size is important. If we want to know the basin-scale ocean circulation, the 50 km or 100 km mesh is enough. But it is not enough to know a circulation of a small bay, such as Otsuchi Bay. One of solutions of this problem is the "nested-grid system" (Fig. C1). In the present study, we have to simulate the Pacific Ocean to know the circulation in Otsuchi Bay. So, we adopted a nested-grid model, which is composed by five ocean models (Fig. C2). The horizontal resolutions of the components are about 50 km, 10 km, 2 km, 75 m, and 14 m, respectively. This system can make efficient use of the limited computer resources.

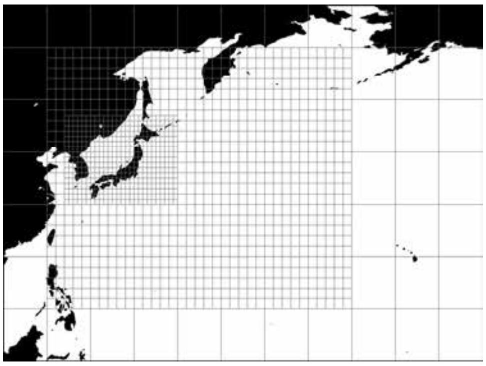

Fig. C1. Example of a nested-grid system.

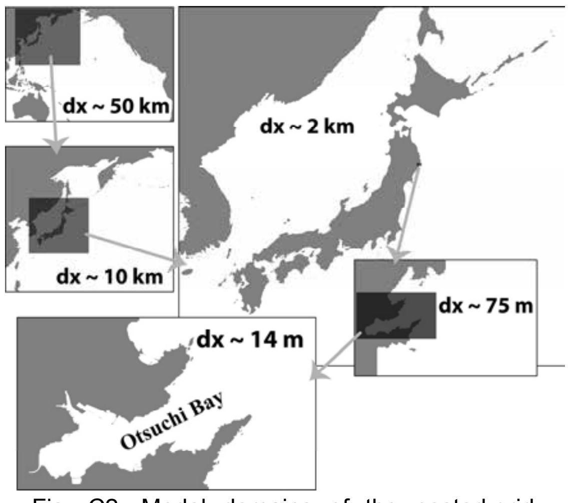

Fig. C2. Model domains of the nested-grid model used in the present study. "dx" means a horizontal resolution.

the bay within several days (Fig. 2, 3a). In summer and autumn, on the other hand, colder water intrusions are occurred at the bottom layer of the bay associated with oscillations whose frequencies are 12 or 24 hours related to tides (Figs. 3b). In these seasons, the water in the bay is strongly stratified, and an observational study suggested that the water exchange between the bay and the North Pacific is frequently occurred by “baroclinic tides” (Tanaka et al. 2016).

【Conclusion】

The numerical simulation in Otsuchi Bay successfully reproduced the less-saline/colder water intrusions into the bay. For more simulated results, please see Sakamoto et al. (2016). Our goal will be to construct a marine ecosystem model to reproduce the environment of the Sanriku ria coastal area.

【Further readings and information】

Sakamoto, T. T. et al. (2016) Numerical simulation of Pacific water intrusion into Otsuchi Bay, northeast of Japan, with a nested-grid OGCM. *Journal of Oceanography*, doi: 10.1007/s10872-015-0344-y

Tanaka, K. et al. (2016) Baroclinic circulation and its variability in Otsuchi Bay on Sanriku ria coast, Japan. *Journal of Oceanography*, doi: 10.1007/s10872-015-0338-9

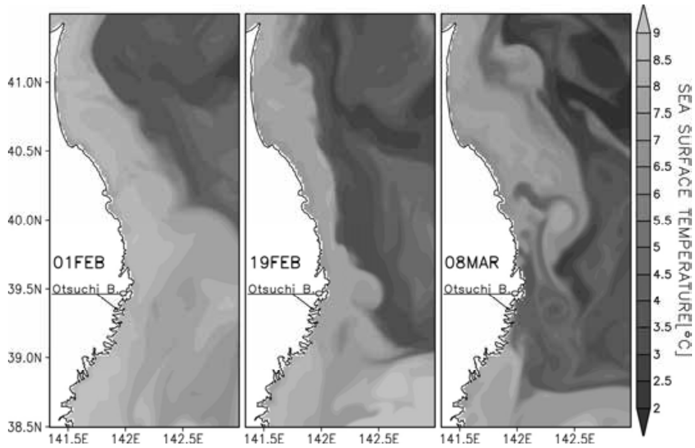

Fig. 1. Simulated sea surface temperature (SST). From left to right, SST on February 1, 19, and March 8 are shown. In February, there is an warm water which is called Tsugaru Warm Water along the coast. On March 8, a cold water from Oyashio approaches at a part of the coast (Sanriku Coast) where Otsuchi Bay is located.

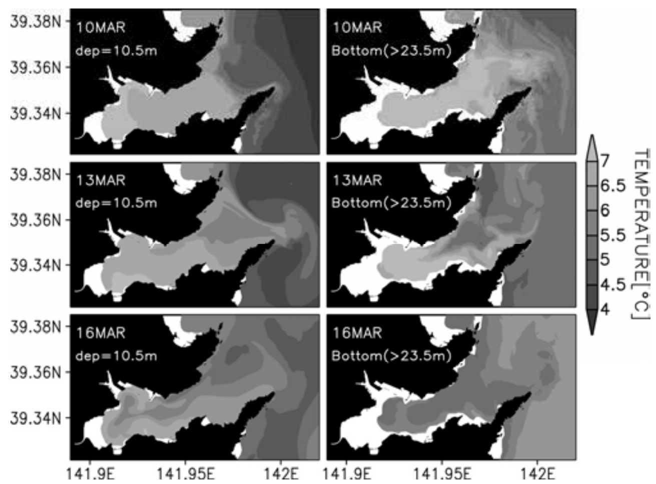

Fig. 2. Simulated seawater temperature in Otsuchi Bay. Left and right panels show the temperatures at 10.5-m depth and at just above the sea floor (deeper than 23.5-m depth), respectively. From top to bottom, the temperature on March 10, 13, and 16 are displayed, respectively. Successively the Oyashio water approaching to the Sanriku Coast (Fig.1), the cold water intrudes into Otsuchi Bay within a several days.

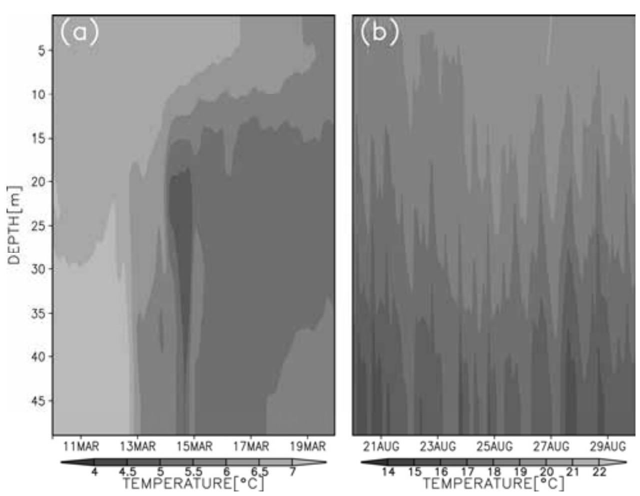

Fig. 3. Time series of the simulated seawater temperature at a central point of Otsuchi Bay from March 10 to 19 (a), and from August 20 to 29 (b). The x- and y- axes show time and depth, respectively. In March, a sudden fall of the seawater temperature caused by a cold water intrusion into the bay (Figs.1, 2) is simulated. In August, on the other hand, cold water intrusions associated with oscillations are occurred at the bottom layer. Periods of the oscillations are almost 12 and 24 hours.

What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

For numerical simulation of Otsuchi Bay; tides in our nested-grid model

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Key words: nested-grid model, tides

【Background】

Otsuchi Bay is one of small bays that exist along the Sanriku ria coast of Japan. Observations have been intensively conducted in this small bay through the project Tohoku Ecosystem-Associated Marine Sciences (TEAMS). Offshore Pacific waters strongly affect the marine environment of this bay. So, it is important for numerical simulation of Otsuchi Bay to well reproduce properties of these waters. We constructed a nested-grid ocean modeling system for this purpose (see the article by Dr. T. T. Sakamoto in this book for detailed information about the nested-grid system).

【Aim】

One of the observational studies associated with TEAMS reveals that cold North Pacific water frequently intrudes into the Otsuchi Bay through "baroclinic tides" (Tanaka et al., 2016). In order to reproduce this phenomenon, we need to incorporate tidal forcing into our system. Here, we show how tides are represented in our model.

【What we found】

Figure 1a shows amplitudes of M_2 tide (one of major tidal constituents) reproduced in an ocean tide model (NAO.99b; Matsumoto et al., 2000), which is often used as a reference state of tidal amplitude. Here, it is compared to the results of our modeling system. Tidal force in our model is calculated from positions of astronomical bodies (the sun, the earth and the moon). The first version of our modeling system covers whole area of the North Pacific Ocean and a partial area of the South Pacific Ocean. The southern boundary is located around the northern limit of the Australian continent. It is found that this model cannot reproduce realistic amplitude of tides (Fig. 1b). We extended the model domain in the second version of our system. Its southern boundary lies around the southern limit of the Australian continent. This system well reproduces the spatial pattern of tidal amplitude (Fig. 1c) but its magnitude is larger than the reference state (Fig. 1a).

This is because "dissipation processes" cannot be represented in our modeling system. Tidal currents interact with ocean topography and generate "internal waves". This wave generation leads to weakening tidal amplitude. It is not feasible to explicitly represent this process over the Pacific Ocean with the current computational resources. So, this effect must be parameterized and incorporated into our model. We adopt a method proposed by Jayne and St. Laurent (2001) and our modeling system succeeds in reproducing realistic tidal amplitude (Fig. 1d).

【Conclusion】

Tidal forcing in our modeling system is calculated from positions of astronomical bodies. Spatial pattern of tidal amplitude in the model depends on the model domain. Covering the whole area of the Pacific Ocean, our model well reproduces the distribution of tidal amplitude. The tidal amplitude in our model becomes more realistic by incorporating the parameterization of "dissipation processes". Sakamoto et al. (2016) use this modeling system and simulate the water exchange between the Otsuchi Bay and the Pacific Ocean that is found in the work of Tanaka et al. (2016).

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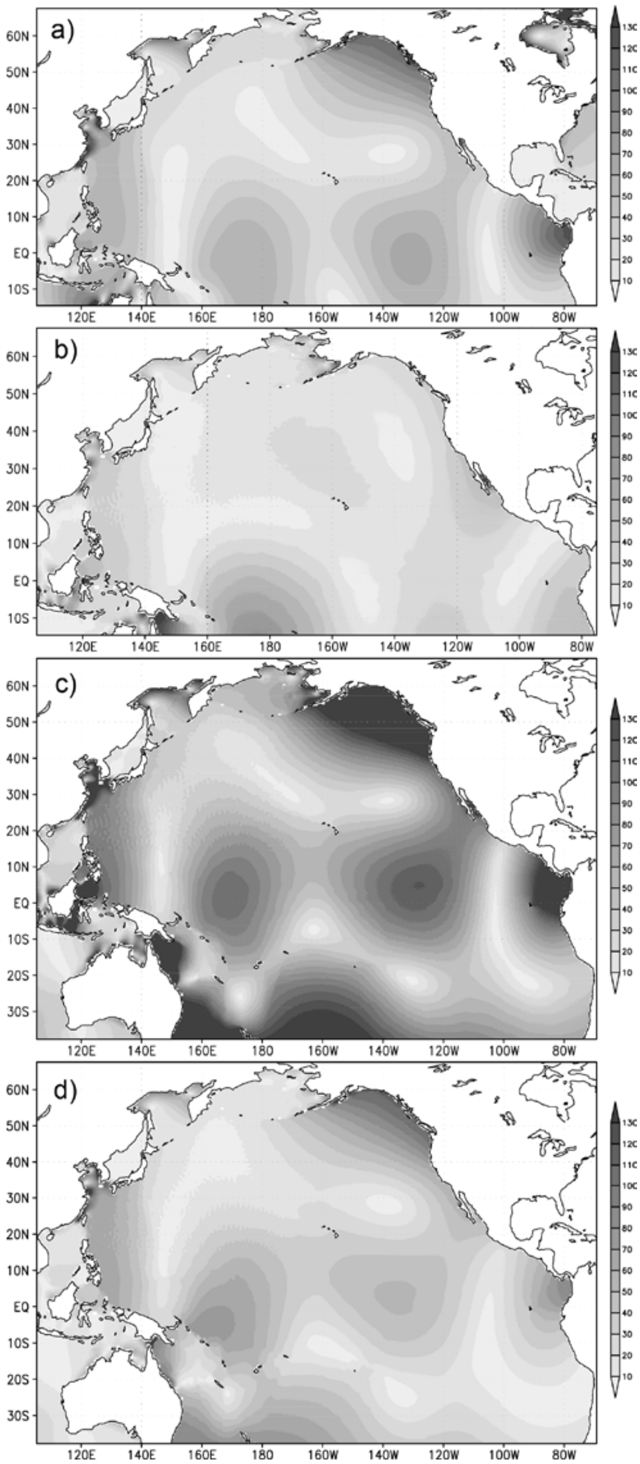

Fig. 1. Amplitude of M_2 tidal constituent (a) in NAO.99b, (b) in the first version of our system, (c) in the second version of our system without parameterization of Jayne and St. Laurent (2000) and (d) in the second version of our system with parameterization of Jayne and St. Laurent (2000). Unit is cm.

【How we investigated】

Our nested-grid ocean model is based on a coupled sea ice-ocean model, IcedCOCO, which is developed in Atmosphere and Ocean Research Institute and Japan Agency for Marine-Earth Science and Technology. The numerical experiments are conducted with the use of Fujitsu PRIMEHPC FX10 system in the Information Technology Center, the University of Tokyo.

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Sakamoto, T. T. et al. (2016) Numerical simulation of Pacific water intrusion into Otsuchi Bay, northeast of Japan, with a nested-grid OGCM. *Journal of Oceanography*, doi:10.1007/s10872-015-0344-y.

Tanaka, K. et al. (2016) Baroclinic circulation and its variability in Otsuchi Bay on Sanriku ria coast, Japan. *Journal of Oceanography*, doi:10.1007/s10872-015-0338-9.

What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Semidiurnal tidal current in Onagawa fishery port, Japan, after the 2011 off the Pacific coast of Tohoku Earthquake

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Key words: semidiurnal tidal current, baroclinic flow, internal tide, Onagawa fishery port

【Background】

In the coastal ocean, tidal currents play an important role in water exchange, ocean mixing and material transport processes, and these flow patterns influence sedimentation and resuspension processes. In Onagawa fishery port, the 2011 off the Pacific coast of Tohoku Earthquake and the tsunami accompanied by the earthquake destroyed coastal protection facilities such as breakwaters and quay walls and caused subsidence. After the earthquake, these coastal protection facilities have been restored, resulting in continuous changes of the coastline and bottom topography. These changes might influence semidiurnal tidal currents in the fishery port after the earthquake.

【Aim】

To investigate features of the semidiurnal tidal current in Onagawa fishery port after the 2011 off the Pacific coast of Tohoku Earthquake.

【What we found】

Seasonal and interannual variations of the semidiurnal tidal current at a depth of 2 m were distinct. In 2014, the stronger tidal currents with speeds exceeding 1 cm s^{-1} were frequently found during the period from May to October. In particular, during the period from July to September, the tidal current was intermittently enhanced. On the other hand, in 2015, the tidal current also became stronger during the period from July to September, but the current speed was smaller than that in 2014. Additionally, the tidal current was also intermittently enhanced in April 2015 (Fig. 1a).

The summertime tidal current was characterized by baroclinic flow; that is, vertically reverse flow between depths of 2 and 10 m was dominant, and its amplitude at a depth of 10 m tended to be larger than that at a depth of 2 m (Fig. 1b).

During the period from March to October in 2014 and 2015, salinity was lower than 33.0 in the upper layer, and less-saline water (LW) often appeared in the surface layer. The appearances of LW tended to be accompanied by rain. In April and September 2015, salinity of LW was much lower. However, there was not much precipitation just before or during the

What is internal tide?
Internal tides are ubiquitous features in the coastal ocean. They are caused by interaction of barotropic tidal flow with bottom topography such as a shelf break or a seamount in a stratified ocean. Their flow structure is characterized by baroclinic flow such as vertical reverse flow between upper and lower depths. They are largely influenced by bottom topography; that is, they are dramatically amplified when the characteristic slope of the internal tide is close to the bottom slope. They are considered to decay within a relatively short distance from the generating region by giving up their energy to vertical mixing. Some efforts have been made to relate this energy dissipation to the enhanced biological production observed near shelf breaks.

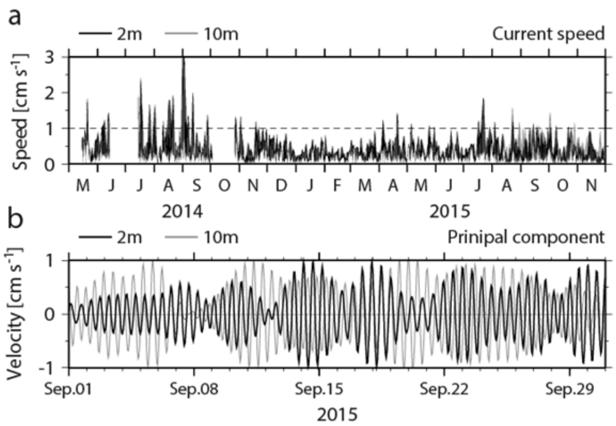

Fig. 1. Time series of (a) the current speed of the semidiurnal tidal currents at depths of 2 and 10 m during the period from May 2014 to November 2015 and of (b) these principal components in September 2015.

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appearance of LW in April 2015, instead Oyashio water (OW) intruded in the lower layer. According to time series of ϕ, the temporal variation of stratification showed clear seasonality; namely, the stratification became stronger during the period from May to September, but the strongest stratification formed in April 2015. Additionally, the stratification fluctuated on time scales of shorter than one month. The seasonal and short term fluctuations of the stratification corresponded to those in the appearances of the low-salinity water (S < 33.0) and LW, respectively (Fig. 2).

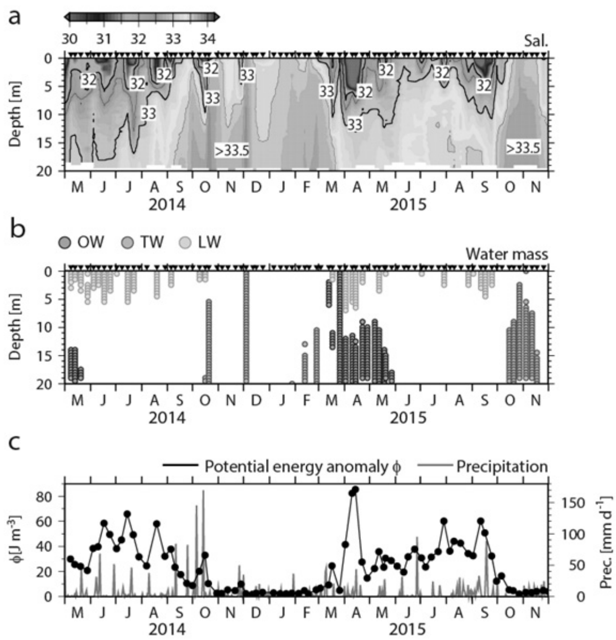

Fig. 2. Depth-time diagrams of (a) salinity and of (b) the water mass: Oyashio water (OW); Tsugaru Warm Current water (TW); Less-saline water (LW) during the period from May 2014 to November 2015. (c) Time series of potential energy anomaly ϕ and precipitation during the same period. Black and gray lines in (c) denote the potential energy anomaly ϕ and the precipitation, respectively.

【Conclusion】

1. Seasonal variation of the semidiurnal tidal current is characterized by summertime enhancement.
2. Interannual variation of the semidiurnal tidal current is characterized by summertime weakening over 2014 and 2015.
3. The summertime semidiurnal tidal current is regarded as internal tide because it was characterized by the vertically reverse (baroclinic) flow and developed in a stratified ocean.
4. There is the possibility that development of the semidiurnal tidal current is accompanied by the intrusion of Oyashi water with LW in the surface layer because of enhancement of the stratification.

【How we investigated】

・ Mooring observations of currents have been conducted since May 2014. The installed mooring system was fitted with a current meter at a depth of 2 m during the period from May 2014 to July 2015 and was fitted with two current meters at depths of 2 and 10 m since August 2015. The semidiurnal tidal currents were extracted using a band-pass filter with a 11.3-hour and 13.7-hour half power point. The semidiurnal tidal currents at depths of 2 and 10 m were decomposed into fluctuating components along the principal axes of 110-113° and 126° measured counterclockwise from east, respectively.

・ Stationary observations of water temperature, conductivity, depth, chlorophyll a, dissolved oxygen and turbidity by CTD have been conducted at about 7-day intervals since July 2012. Water mass classification for the obtained water temperature and salinity profiles was conducted on the basis of seven water systems, which consist of six water systems proposed by Hanawa and Mitsudera (1987) and "less-saline water (LW)" defined as S < 32.0 in the present study. In order to examine stratification in the entire water column, potential energy anomaly per unit volume ϕ was calculated. This variable has been used as an indicator of vertical stratification.

・Precipitation was investigated using data from an Automated Meteorological Data Acquisition System (AMeDAS) station.

【Further readings and information】

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Some data are available at the followings;
http://www.jamstec.go.jp/teams/e/data.html
http://www.agri.tohoku.ac.jp/teams/index.html

Some prompt reports of oceanographic conditions in Sanriku Coastal Area are available at the follows;
http://www.agri.tohoku.ac.jp/teams/index.html

Effluent and transportation of terrigenous organic matter to Otsuchi Bay and its offshore area by the huge tsunami in 2011

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Key words: terrigenous organic matter, organic pollutants, huge tsunami, Otsuchi

【Background】

The huge tsunami induced by Great East Japan Earthquake in 2011 caused serious damage to the Sanriku coast areas. A large amount of materials on land (terrigenous materials), including both natural and anthropogenic origin, was flowed out by the tsunami backwash into adjacent sea areas. Moreover coastal sediments were greatly disturbed and might be transported partly into the offshore area, in which past-accumulating terrigenous materials were buried. If significant amount of pollutants as well as natural terrigenous materials spread over the coastal and/or offshore areas throughout these events, the local fisheries activity should sustain serious damage. Therefore, it is very important for supporting the fisheries recovery to elucidate the extents and distributions of pollutants in the coastal areas after the tsunami and to monitor their changes in the long term.

【Aim】

To see the extents and distributions of molecular markers of organic pollutants such as PCBs (polychlorinated biphenyl), hopanes, LABs (linear alkylbenzene) and PAHs (polycyclic aromatic hydrocarbon) as well as biomarkers of natural terrigenous organic matter, i.e. C:N ratio, $\delta^{13}C$ and lignin-derived phenols in the sediments of Otsuchi Bay and its offshore areas, and to monitor their changes in the long term after the tsunami.

【What we found】

The concentrations of molecular markers of organic pollutants of the sediments in Otsuchi Bay were basically on a lower or similar level compared with those in other coastal areas especially adjacent to urban regions such as Tokyo Bay. On the other hand, the natural terrigenous biomarkers indicated a significant increase in the contribution of terrigenous origin to the surface sediments outside the bay after the tsunami. According to the detailed observation in the offshore areas, it was evident that the enrichment of natural terrigenous biomarkers accompanied by a small amount of organic pollutants, spread up to ca.10 km point from the center of the bay.

【Conclusion】

It was found that there were no serious problems due to the spread of the organic pollutants of the sediments in Otsuchi Bay and its offshore areas during about five years after the tsunami. However, it was evident that there was a significant effluent of terrigenous organic matter including pollutants from Sanriku coast to its offshore areas. Monitoring the changes in their distributions in the long term should be important for supporting sustainable activity of local fisheries.

【How we investigated】

We are monitoring the molecular markers of organic pollutants and the biomarkers of natural terrigenous organic matter in the surface sediments collected at a few stations in Otsuchi Bay at intervals of two months from May 2011. Core sediments samples in the offshore areas were collected by a multiple sediment core sampler (Fig.1, 2) on the two cruises of R/V Shinsei Maru (JAMSTEC) in 2013 and 2014. The molecular markers of organic pollutants and the lignin-derived phenols as a biomarker of natural terrigenous organic matter were measured at Tokyo University of Agriculture and Technology, and other parameters analyses were conducted at Atmosphere and Ocean Research Institute, The University of Tokyo.

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【Further readings and information】

R/V Shinsei maru Research vessel was built as a part of TEAMS. Please visit the web site for details; http://www.jamstec.go.jp/e/about/equipment/ships/shinseimaru.html

Fig. 1. Core sediment sample collected at station OT-3 in offshore areas of Otsuchi Bay.

Fig. 2. Multiple sediment core sampler on the R/V Shinsei-maru.

The fate of terrigenous dissolved organic matter in Otsuchi Bay, Japan: The implication from a decomposition experiment

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Key words: terrigenus dissolved organic matter (tDOM), lignin phenols, degradation, Otsuchi Bay

【Background】

Terrigenous dissolved organic matter (tDOM) in the ocean is very rare and it is mainly transported by river input. Lignin phenols (LP) are the unique biomarker to study tDOM in the ocean due to the original source comes from land plants. Meanwhile, the removal process of tDOM is a key to better understand the global carbon cycles in the ocean. Otsuchi Bay is a high potential area to study tDOM in seawater because river inflow affects the carbon pool and biogeochemical cycles in this bay. Moreover, the impact of tsunami associated with the 2011 Tohoku earthquake to the carbon pool in this bay is still unclear.

【Aim】

To understand the removal mechanism of tDOM, we conducted a laboratory decomposition experiment. This experiment results provided us more information to realize tDOM diagenesis in Otsuchi Bay.

【What we found】

Concentration of LP decreased rapidly and nearly 50% was removed during the early 20 days in the light treatment, but a small fraction (ca. 10%) of LP was removed in the dark treatment. The next 42 days, additional ca. 10% of LP concentrations were removed in the light treatment, and ca. 30% of those were removed in the dark treatment. Our results suggested that lignin phenols were highly susceptible to photodegradation and resisted to biodegradation. Moreover, a tendency of increasing in biodegraded contribution was observed in this tDOM decomposition experiment. The relative contribution between photo- and bio- degradation with incubation time is shown in Fig. 1. The removal fraction of tDOM causing by photodegradation was getting smaller, in contrary, the fraction of biodegradation became higher in the later period.

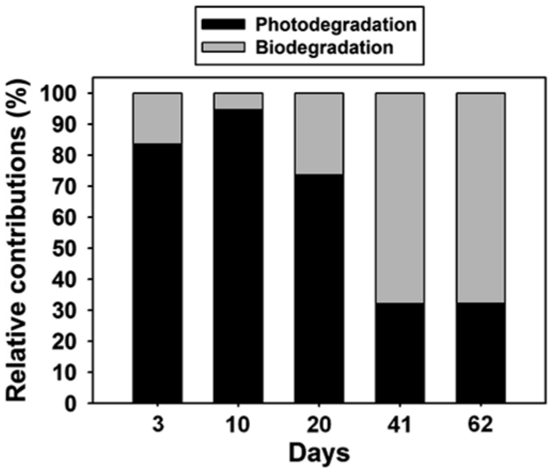

Fig. 1 Relative contributions of photodegradation and biodegradation with time-course from tDOM decomposition experiment.

What is lignin?
Lignin (Latin "*lignum*" means "wood") occurs in cell walls of terrestrial vascular plants and it is absent in marine organisms. Therefore, lignin is a good biomarker to trace the input of tDOM in the ocean. Chemically lignin is a phenolic polymer, and the most widely studied lignin-derived phenols are including vanilly, syringyl and cinnamyl phenols. It can reveal the information about vegetation sources (e.g., angiosperm and gymnosperm) and tDOM degradation in seawater by quantifying those lignin-derived phenols concentrations.

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【Conclusion】

1. Irradiance dose plays an important role in tDOM degradation processes especially to LP. tDOM decomposition was highly associated with photodegradation in natural environment.
2. Biodegradation dominated tDOM diagenesis with long-term incubation. In other words, if the residence time of tDOM is longer, biodegradation will be the main factor controlling tDOM diagenesis in the ocean.
3. Moreover, physical mixing is another important factor of tDOM removal mechanism in Otsuchi Bay, especially the river-seawater exchange rate is very high. The seasonal seawater LP concentrations results also provided a good evidence that tDOM in this bay was highly affected by physical mixing.

【How we investigated】

The Unosumai River water was collected in July 2013 and we incubated the river water for 2 months to discover the removal mechanism of tDOM in Otsuchi Bay. The experiment was conducted light and dark treatments to respectively recognize as photo- and/or bio- degradation (light treatment) and biodegradation (dark treatment). Sample was filtered through 1 μm Whatman® polycarbonate filter to extract dissolved lignin phenols. Dissolved LP concentrations were measured as tDOM in filtrate.

【Further readings and information】

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What happened to the marine environments after Great East Japan Earthquake ?
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Distributions and biogeochemical cycles of platinum in Otsuchi Bay after the tsunami in 2011

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Key words: Platinum, anthropogenic, Otsuchi

【Background】

Otsuchi Bay in Iwate Prefecture located at Pacific Ocean side in North Japan. In this area, the 2011 off the Pacific coast of Tohoku Earthquake occurred in March 11 2011, and thereafter giant tsunami attacked this coastal area. Many coastal areas have been damaged catastrophically, then many of artificial things on land are flowed by the tsunami. It is thought that coastal environments were affected by terrestrial materials, not only natural materials (e.g. sediments, plants), but also artifacts on land.

Recently, platinum has been used as industrial materials, for example automobile catalysis and anticancer drugs. Possibly, industrial materials like platinum are affecting the estuary environment.

【Aim】

We revealed distributions of the dissolved platinum in waters at Otsuchi Bay after the tsunami, and traced their spatial and temporal variations. Then, we discuss the variation of the platinum in Otsuchi Bay before and after the tsunami.

【What we found】

Dissolved platinum concentrations ranged from 0.24 to 5.18 pmol/L in seawater and were higher than that of open ocean seawater. Pt concentrations in river water samples were below than the detection limit (0.015 pmol/L). The concentrations in bottom water are higher than those in surface water. The trend shows that dissolved platinum are supplied from the sea floor.

Compared with the platinum concentrations in surface seawater before and after the tsunami, platinum concentrations became high in all the sampling points of Otsuchi Bay after the tsunami.

【Conclusion】

Huge amounts of terrestrial materials, including platinum, were transported from river water to the bay by the tsunami. In the upper estuary, dissolved platinum is adsorbed by suspended particulate matter, and settled to the bottom sediments. After the lateral transportation, platinum is released from the bottom sediments at high salinity area (Fig. 1).

After tsunami, more platinum is released from the sediments because of transported terrestrial materials on sea floor.

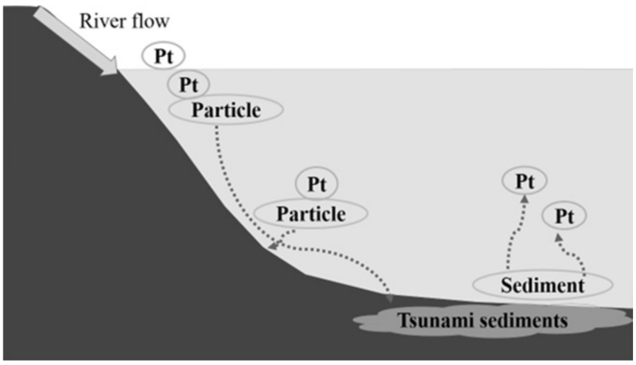

Figure 1. How the platinum is released in seawater

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【How we investigated】

Sea water samples were collected from Otsuchi Bay in Iwate Prefecture (Fig.2). We collected seawater samples by using research boat like the Fig. 3. We used an acid-cleaned X-Niskin bottle onboard the boat. Seawater samples were also filtrated onboard the boat. Dissolved platinum concentrations were determined in laboratory (Suzuki et al., 2014). We used isotope dilution method with an inductivity coupled plasma mass spectrometer (ICP-MS).

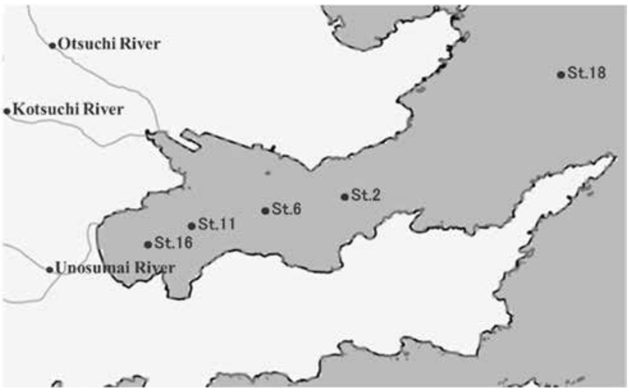

Figure 2. Sampling points in Otsuchi Bay

【Further readings and information】

A. Suzuki, H. Obata, A. Okubo and T. Gamo. (2014) Precise determination of dissolved platinum in seawater of the Japan Sea, the Sea of Okhotsk and the western North Pacific. *Marine Chemistry*, 166, 114–121.

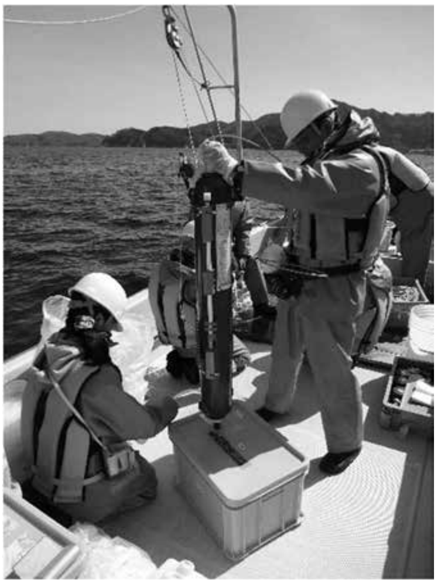

Figure 3. Sampling and filtration onboard the research boat (3/12/2013)

What happened to the marine environments after Great East Japan Earthquake？
TEAMS International Conference, March 2016

A monitoring result of polychlorinated biphenyls (PCBs) in deep-sea organisms and sediments off Tohoku during 2012-2014

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Key words: PCBs, trophic position, deep-sea fish, sediment

【Background】

The 2011 off the Pacific coast of Tohoku Earthquake attacked the coast of northern Japan on March 11, 2011. It induced an extremely destructive tsunami that washed away as large as 25 million tons of debris from the Pacific coast of Tohoku area (Bagulayan 2012). The debris included a number of old electric equipment containing high-level polychlorinated biphenyls (PCBs) that had been stored in the coastal areas. Immediately after the tsunami event, one of the major concerns is the marine environmental pollution with toxic chemicals. During the tsunami event, these electric equipment potentially broke and PCBs spilled out from them. Otherwise, they might be buried in the sediment off Tohoku region and contaminate the marine environment in the long run.

【Aim】

We report our monitoring results of PCBs in benthic fish and invertebrate collected from a relatively narrow area mainly off Miyako and Kamaishi Cities, and surface sediments collected from off Tohoku after the earthquake (Ohkouchi et al., revised).

【What we found】

Total concentration of PCBs in our deep-sea fish and invertebrate samples ranges 0.12 to 51 ng g^{-1} dry weight with the mean of 5.3 ng g^{-1} dry weight. This range is well below the regulatory srandard for pelagic fish (500 ng g^{-1} dry weight) determined by Ministry of the Environment in Japan. Although most fish samples exhibited the concentration lower than 5 ng g^{-1} dry weight, some specific fish species showed substantially higher than this value. The highest concentration was observed in edible synaphobranchid fish (*Synaphobranchus kaupii*) which shows 51 ng g^{-1} dry weight for the specimen collected at 501 m depth in July 2012. The same species collected at 350 m depth in April 2013 shows the second highest value, 47 ng g^{-1} dry weight. In terms of lipid-weight normalized concentration, total PCBs range from 9 to 374 ng g^{-1} lipid. They are similar with or lower than those reported by previous reports.

In 19 sediment samples, total concentration of PCBs ranges 0.086 to 4.0 ng g^{-1} dry sed., somewhat lower than the biological samples. These values are also well below the regulatory standard for pelagic sediment (10 μg g^{-1} dry sed.) determined by Ministry of the Environment in Japan. The highest total PCB concentration (4.0 ng g^{-1} dry sed.) is observed in the subsurface (2.5–5.0 cm) sediments recovered from N-870 site off Kamaishi City at 870 m depth in March 2012. Our sediment samplings were conducted in March 2012 and October-November 2013. Total PCB concentrations of the sediments from 2013 are somewhat lower than those from 2012. Among these sediment samples, relative contribution of PCB congeners is not significantly different except for the

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sample showing the highest PCB concentration. In most samples, the dominant PCB congeners are either tetra- or penta-PCBs, which is followed by tri- and hexa-PCBs, whereas in the sample #43, hepta-PCBs were most abundant. Highly chlorinated PCBs were more enriched in the biological samples (Fig. 2). The water depth profile of sedimentary PCBs demonstrated that the total PCBs concentration in deeper water (>800 m) is somewhat higher than those of shallower water (300–550 m).

In year 2005, PCB concentration of synaphobrachid fish (*Simenchelys parasitica* and *S. kaupii*) ranges 26 to 2000 ng g^{-1} dry weight with some being higher than the regulatory standard. However, in year 2012 and 2013, it is around 50 ng g^{-1} dry weight. Overall, across the tsunami event in March 2011, total PCBs levels in such fishes do not exhibit apparent increase. The graph suggested that the PCBs washed away into the sea by the tsunami have not widely polluted at least the research during 2012–2014.

【Conclusion】

Overall, we demonstrated that the total PCB concentrations in various deep-sea organisms and sediments recovered during 2012-2014 have similar level with those before the 2011 tsunami event associated with the 2011 off the Pacific coast of Tohoku Earthquake. Currently, they are one to two orders of magnitude smaller than the regulatory standard value determined by Ministry of the Environment in Japan. We concluded that the PCBs-containing electric equipment washed away by the tsunami did not significantly polluted at least in our sampling region (200–900 m depth) off Iwate Prefecture until spring of 2014.

【How we investigated】

Deep-sea fish and invertebrate samples (39 samples) were collected from off Tohoku coast (an area covered from 39°06.741’N to 39°47.645’N, and from 142°04.855’E to 142°16.212’E) from depths ranging from 220 to 501 m during several cruises of R/V *Iwate-maru* from November 2011 to April 2014. Surface sediment samples were collected by using a multiple-corer from bathyal sites off Tohoku, during the R/V *Mirai* cruise MR12-E02 in March 2012 and the R/V *Bosei-maru* cruise BO13-20 in October/November. Three east-west direction lines located at 39°15' N (N-line), 38°30' N (M-line), and 37°53' N (S-line), were selected with water depths ranging from 310 m to 880 m.

PCB analysis was conducted with the analytical method basically follows the procedures described in the manual published by Ministry of the Environment.

【Further readings and information】

Ohkouchi, N., Shibata, H., Chikaraishi, Y, Ogawa, N.O., Nagata, T., Goto, T, Fujikura, K. and Kitazato, H., A monitoring result of polychlorinated biphenyls (PCBs) in deep-sea organisms and sediments off Tohoku during 2012–2014: Temporal variation and the relationship with the trophic position. *Journal of Oceanography,* (revised).

What happened to the marine environments after Great East Japan Earthquake?
TEAMS International Conference, March 2016

Spatial distribution and temporal trend of anthropogenic organic compounds derived from the 2011 East Japan Earthquake

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Key words: mussel watch, anthropogenic organic compounds, PCBs, LABs PAHs

【Background】

The coastal environment in east side of Tohoku district was disturbed by Tsunami derived from the earth quake on March 11th, 2011. Numerous terrestrial materials, including anthropogenic organic compounds, were supplied to the coastal zones. These compounds include synthetic chemicals and petroleum hydrocarbons. It is important to assess the environmental pollution by these compounds in the coastal area caused by the Tsunami.

Mussels are a kind of bivalves and they have been used for environmental monitoring media of hydrophobic organic compounds as “Mussel Watch”. Blue mussels (*Mytilus galloprovincialis*) are one of mussel species and inhabit the coastal area of Japan, including the area impacted by the Tsunami.

【Aim】

The purpose of the research is to elucidate the concentrations and temporal trends of anthropogenic organic compounds in the coastal areas of Tohoku district after the Tsunami.

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What’s Mussel Watch?

Mussel Watch is a conventional method for environmental monitoring using mussels which inhabit in coastal area.

International and regional monitoring projects such as International mussel watch and Asian mussel watch have been carried out. It is useful for environmental monitoring after disaster.

The advantages of mussels as monitoring media for hydrophobic organic compounds are the followings.

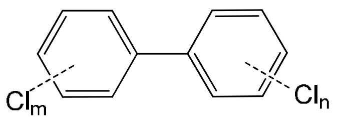
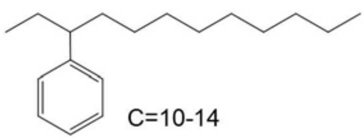
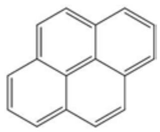
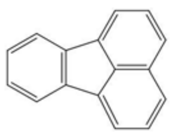
1. Cosmopolitan
Mussel and related species are available in coastal zones all over the world. They are easy to be collected due to the wide availability and large population.

2. Bioconcentration
Mussels can concentrate hydrophobic organic compounds in lipids of their soft tissue from ambient seawater.

3. Sedentary
Since they are not movable, the concentration of contaminants in their tissue reflects that in ambient seawater.

4. High tolerance to pollution
As they have high tolerance against marine pollution, they can live in polluted environments.

Table 1 Target compounds in the present research

PCBs (Polychlorinated biphenyls)	LABs (Linear alkylbenzenes)	PAHs (Polycyclic aromatic hydrocarbons)
 m+n=1-10		 
・Industrial chemical banned since 1974 in Japan ・Legacy contaminants of PCBs have been still accumulated in the coastal sediment	・Impurity of linear alkylbenzene-sulfonates (LAS), main component of household synthetic detergents ・A molecular marker of sewage	・Combustion product of organic matter (fossil fuel and biomass) ・PAHs are contained also in petroleum

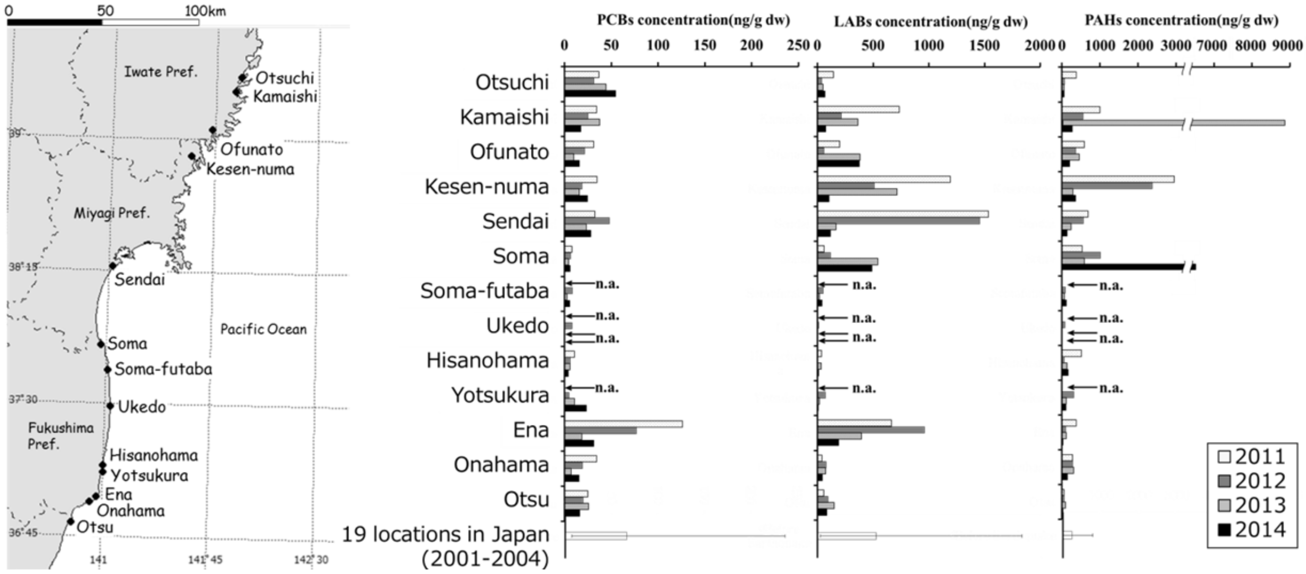


Fig.1 Concentrations of anthropogenic organic compounds in mussels collected from 13 locations during 2011-2014

【What we found】

The target compounds were detected in all the locations and years which we analyzed. Various temporal trends were observed among locations and compounds (Fig.1).

In some locations, the concentrations of the target compounds were the highest in 2011 among the 4 years and have been decreasing thereafter. For PCBs and LABs, even the highest concentrations in 2011 were lower than the maximum concentrations in Japanese Mussel Watch (JMW) conducted in 2001-2004. Though the highest concentrations of PAHs in 2011 exceeded the maximum concentration of JMW, the PAH concentrations have decreased and those in 2014 were below the maximum concentration.

Sources and mechanisms of the temporal trends are considered as follows.

PCBs: Resuspension of sediment sorbing legacy PCBs by the Tsunami and subsequent re-settlement.

LABs: Damages of sewage treatment plants and sewer by the disaster and their misfunctioning and their subsequent recovery.

PAHs: Damages of land-based and nearshore oil facilities (e.g., tanks, pipelines, and tankers) and runoff of spilled oil by flow off the land of the Tsunami waters and their subsequent sedimentation and degradation of the compunds.

On the other hand, the higher concentrations of LABs and PAHs were detected even after 2013 at several locations. This can be explained by the human activities involving clean-up, reconstruction and restoration, and the associated increased inputs of the contaminants.

【Conclusion】

Pollution of the anthropogenic organic compounds induced by the Tsunami has been reduced during these 4 years. However, emerging environmental pollution derived from clean-up, reconstruction, and restoration has been suggested at some locations. To understand the long-term trend and consequence of environmental pollution induced by the disaster, continuous monitoring in the Tohoku coasts should be conducted.

【How we investigated】

We analyzed anthropogenic compounds such as PCBs, LABs and PAHs in soft tissue of mussels which were collected from 13 locations in east side of Tohoku district during 2011-2014. To evaluate the impacts of the Tsunami, we compared the results of this study to Japanese Mussel Watch conducted in 2001-2004 where mussels were collected at 19 locations in Japan including industrial and rural area.

The soft tissues of the collected mussels were pooled, homogenized and freeze dried. The freeze-dried mussels were extracted by organic solvent and cleaned- up by silica gel and gel permeation chromatography. PCBs were analyzed on gas chromatograph (GC)- electron capture detector and LABs and PAHs were analyzed on GC-mass spectrometer.

【Further readings and information】

Farrington J.F. et al., U.S. "Mussel Watch" 1976-1978: an overview of the trace-metal, DDE, PCB, hydrocarbon and artificial radionuclide data. *Environmental Science and Technology*, vol.17, p.490–496, 1983

NOAA, Mussel Watch Project : https://data.noaa.gov/dataset/national-status-and-trends-mussel-watch-project

Isobe T. et. al., Hydrocarbons (PAHs) and phenolic endocrine disrupting chemicals in South and Southeast Asian mussels. *Environmental Monitoring and Assessment*, vol. 135, p. 423–440, 2007

Mussel shell recorded the coastal environmental change induced by the huge Tsunami

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Key words: environmental reconstruction, sclerochronology, trace element analysis

【Background】

Huge tsunami induced by the Pacific Coast of Tohoku Earthquake on 11th March 2011 had devastating effect on shallow marine ecosystems in northern Japan.

Nevertheless, a lack of pre-event data often hampers investigations focusing on the impact of the tsunami on ecosystems, as comparisons between pre- and post-event conditions are rarely possible.

Here we investigated the impact of the tsunami on the coastal environment based on trace element analysis of the bivalve shell, in which time series environmental information was recorded with its incremental growth.

【Aim】

The aim of this study is to reconstruct "What happened to the marine environments after Great East Japan Earthquake ? " by geochemical and sclerochronological analysis of mussel shells collected from Otsuchi Bay.

【What we found】

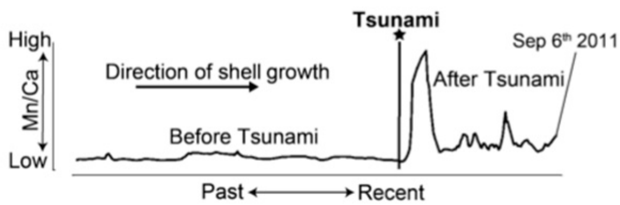

Fig. 1 Profiles of Mn/Ca ratio in the mussel shell along with growth direction. Direction of growth is left to right.

Shell Mn/Ca showed low level before the tsunami, but it increased immediately after the tsunami. This Mn/Ca peak continued about a month. After the peak, shell Mn/Ca ratio showed higher value than that before the Tsunami until half-year later.

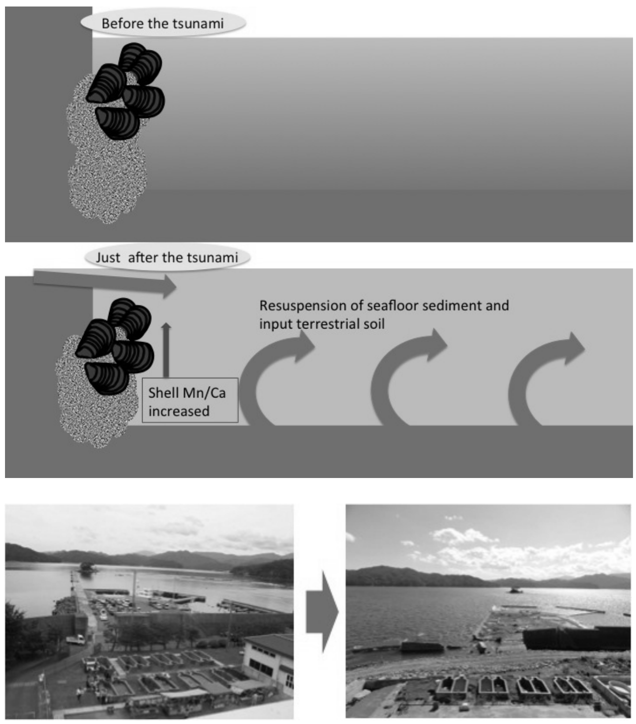

Fig. 2 Schematic image of the process of shell Mn/Ca changes induced by Tsunami.

【Conclusion】

Mn concentration is relatively high in terrestrial soil and seafloor sediment, compared to the seawater. After Tsunami, land subsidence caused the terrestrial soil to be more movable condition resulted in high input into the ocean. This caused increasing of base line of Mn/Ca ratio in the mussel shell.

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【How we investigated】

[Sample collection]

On September 2011, live specimens of the Mediterranean mussel *Mytilus galloprovincialis* were collected from intertidal zone of Otsuchi Bay where was seriously affected by the tsunami. Shells were cut along the maximum growth axis, and the cut surface was polished.

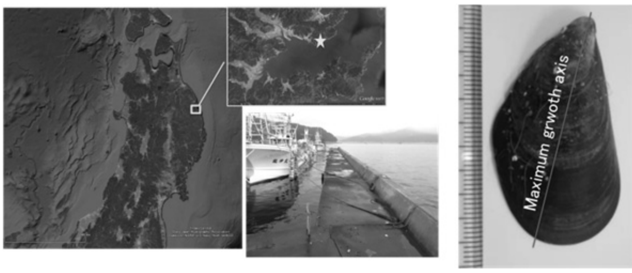

Fig. 3 Studied area and sampling location of Otsuchi Bay.

[Trace element analysis]

We analyzed trace element composition on the shell cross section along the growth direction using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). Spot size was 100 μm.

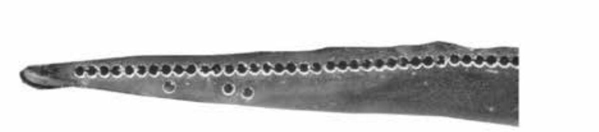

Fig. 4 Spots of LA-ICP-MS analysis. Spot size was 100 μm

[Age model]

To establish an age model, we also observed micro growth patterns on the etched shell sections. We counted the line formed during spring tide.

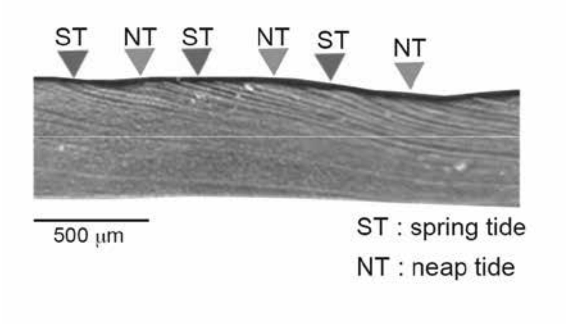

Fig. 5 Etched shell section. Clear narrow lines formed during spring tide, unclear wide lines formed during neap tide.

To confirm growth line observation, we analyzed oxygen stable isotope by IR-MS (Delta V). Oxygen isotope reflect ambient seawater temperature, enabled to estimate the timing of shell formation.

Fig. 6 Grave of subsampling for oxygen isotope analysis.

Obtained data were assigned to the age model.

【Further reading】

Fukuda et al. (2015) *Journal of Oceanography*, 10.1007/s10872-015-0296-2

Chemical substances from marine sediments in Onagawa Bay after Great East Japan Earthquake

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Key words: normal hexane extract, PAHs, radioactivity

【Background】

The tsunami after the Great East Japan Earthquake caused a disturbance of the quality and quantity of chemical substances in the sediment. In addition to this disaster, there was also the accident of Fukushima Nuclear power plant. In response of these events, there were some concerns on what the change in chemical substances would have on the surrounding aquaculture environment. Therefore it was necessary to understand the status of water pollution In regards to chemical and radioactive substances of the coastal area in Miyagi prefecture and especially in Onagawa Bay. For this purpose, we analyzed the distribution and quantity of both normal-hexane extracts and polycyclic aromatic hydrocarbons (PAHs). We also analyzed the influence of detected substances on selected organisms.

【Aim】

To see the change of the chemical substance concentration and radioactivity of coastal sediment in Onagawa Bay.

【What we found】

The amount of normal hexane extract was more than the standard value at some points in Onagawa Bay, but gradually decreased. Main PAHs in the sediments were Pyrene, Fluoranthene, Benzo(a)anthracene, Chrysene and Phenanthrene. Although there was a quantitative difference by a point, the composition of PAHS was approximately the same. Normal hexane extracts showed weak cytostatic ability for normal human cell, but no influence on fish. No influence was observed on human cell line by PAHs.

Relatively high radioactivity (137Cs and 134Cs) was detected at St6 and St21, but radioactivity in the surface layer was decreased. Vertical radioactivity of St 21 was shown in Fig.3.

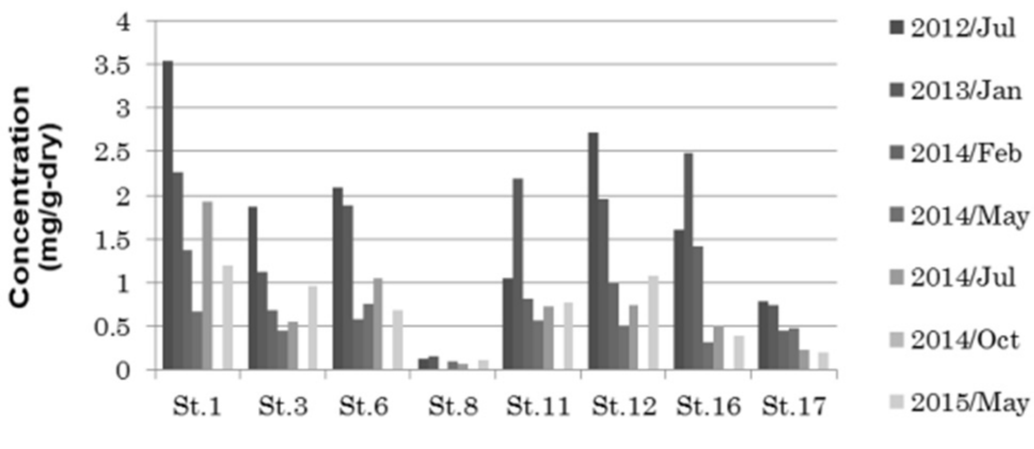

Fig.1 Profile of normal hexane extract contents in the sediment in Onagawa Bay after Great East Japan Earthquake.

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【Conclusion】

1. The amount of normal hexane extract was gradually decreased.
2. PAHs were widely distributed in the coastal sediment of Miyagi Prefecture.
3. Radioactivity was detected in the coastal sediment. The radioactivity of surface layer was decreased.

【How we investigated】

Sample: Coastal sediments from Onagawa Bay, from 2012 to 2015. The sediments were gathered from the surface of the sediment down to 5cm depth for chemical analysis, and both from the radioactivity surface to 5cm and 5cm to 10cm depth for analysis. At some points, sediments were gathered every 1cm.

Analysis: Freeze-dried sediments were extracted with normal hexane, ethanol and normal hexane: acetone (1:1, v/v). Polycyclic aromatic hydrocarbons were analyzed with GC/MS (PAHs analyzer, Agilent). Radioactivity in sediments was detected with Germanium Semiconductor Detector (Ortec).

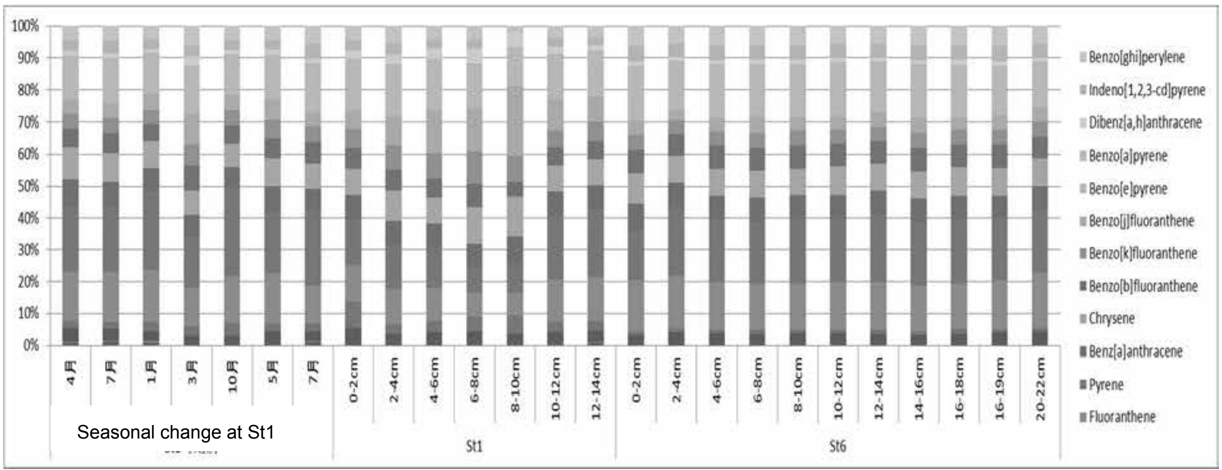

Fig.2 Seasonal change (St1) and vertical profile (St1 and 6) of PAHs in Onagawa Bay

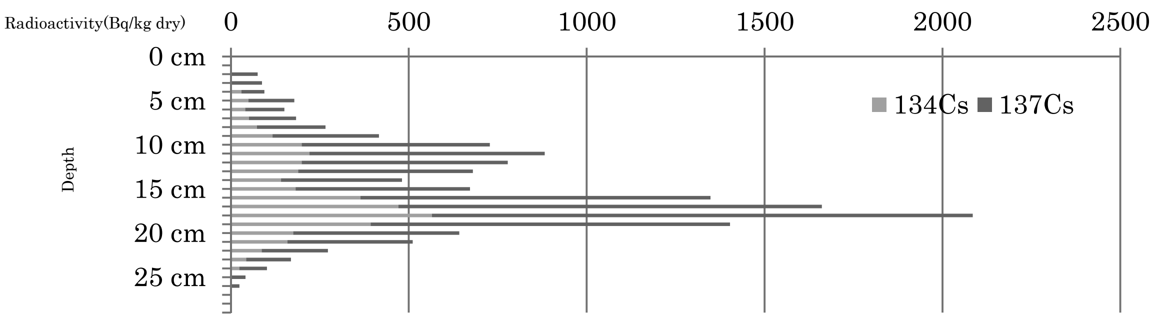

Fig.3 Vertical radioactivity (Bq/kg dry) profile at St21

Distribution of radiocesium released by the 2011 Fukushima nuclear accident in the coastal region of Sendai Bay

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[4] now at Graduate School of Integrated Science and Technology, Shizuoka University, 836 Ohya, Suruga-ku, Shizuoka 422-8528, Japan

Key words: radiocesium, Sendai Bay, inner-shelf sediment

【Background】

Radionuclide emission due to a reactor breakdown at the Fukushima Daiichi Nuclear Power Plant contaminated a wide area of northeastern Japan, including the catchment basin of Abukuma River system. The anthropogenic ^{134}Cs and ^{137}Cs attached to fine-grained particles have streamed into rivers and transported downstream. Finally, the radionuclides have been discharged into the ocean and have deposited on the seafloor.

【Aim】

To elucidate spatiotemporal and stratigraphic distribution of the anthropogenic ^{134}Cs and ^{137}Cs radionuclide emitted from the Fukushima Daiichi Nuclear Power Plant in Sendai Bay. A transport process from land to sea was also investigated.

【What we found】

Concentration of the anthropogenic ^{134}Cs and ^{137}Cs radionuclides in sediments of Sendai Bay is heterogeneous and a high radioactivity is observed in fine-grained sediments off the Abukuma and Natori rivers (Fig. 1). Radioactive horizons at shallow depths (less than 10 cm from the sea floor) are observed in some sediment columns (Fig. 2).

【Conclusion】

1. Grain suspension in torrential currents is a major pathway for transportation of the anthropogenic ^{134}Cs and ^{137}Cs from land to sea.
2. The anthropogenic ^{134}Cs and ^{137}Cs with fine-grained particles have been deposited on the inner-shelf off the mouth of Abukuma River. The radionuclides have also been concentrated in the inner-shelf sediments off Natori River.
3. Occurrence of radioactive horizons in some offshore sediment columns indicates an ongoing natural process of the radionuclide decontamination.

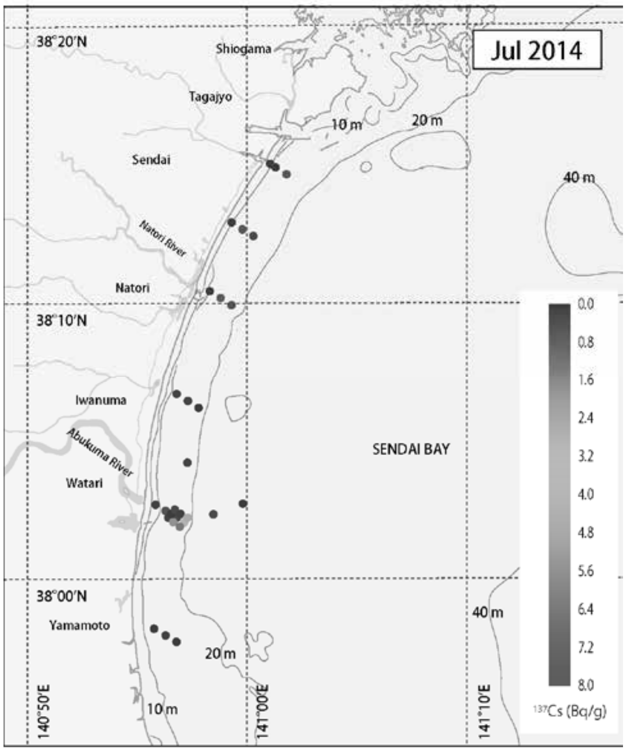

Figure 1 Concentration of ^{137}Cs in sediments collected by the Birge-Ekman grab sampler in July 2014.

【How we investigated】

From March 2012 to September 2015, 10 field surveys were conducted in the coastal region of Sendai Bay. Bottom sediment samples were obtained by the Birge-Ekman grab sampler and Phlegar corer (simple gravity corer) along six fixed lines perpendicular to the coast. Temperature, salinity and oxygen of bottom and surface water were measured by a hand held DO/Conductivity meter (YSI Pro 2030) on board.

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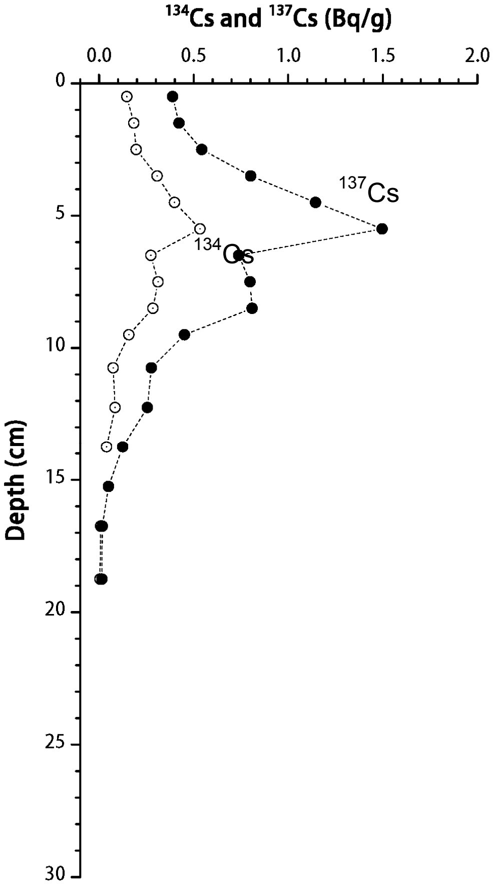

Figure 2 Radioactive horizon observed in sediment column off Abukuma River in November 2013.

Bottom and surface seawater samples obtained by the Niskin water sampler had their conductivity (YEO-KAL Environmental Electronics, Inductively coupled salinometer model 601 MK-IV) and ionic composition (Dionex ICS1100 with AS-AP) analyzed in our laboratory at Tohoku University. Grain size of the sediments were analyzed with laser diffraction particle size distribution analyzers (Shimadzu SALD-3000 and SALD-7000). Radioactivity of the dry sediments were determined by a high-purity coaxial germanium detector (GMX23190-P and GMX30200; EG&G ORTEC, Oak Ridge, Tennessee, USA) at Kyushu University and the gamma-ray spectra were analyzed using the gamma studio software (SEIKO EG&G).

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What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Nutrient status of Otsuchi Bay (northeastern Japan) after Great East Japan Earthquake

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Key words: The 2011 off the Pacific coast of Tohoku Earthquake · Tsunami · Otsuchi Bay · Nutrients · Turbidity

【Background】

On 11 March 2011, the northeast part of the main island of Japan was struck by a massive tsunami associated with the 2011 off the Pacific coast of Tohoku Earthquake. The tsunami caused large disturbances in bottom sediments and severe destruction of natural landscapes, infrastructures and marine biota. One serious and ongoing concern arising from the damage is the alteration of availability of mineral nutrition for marine plants, which may exert a profound influence on the processes of ecosystem recovery and fishery reconstruction in the damaged area.

【Aim】

This study aimed at assessing the nutrient status, which refers to concentrations, chemical composition and composition ratio of major nutrients including nitrate, nitrite, ammonium, phosphate and silicic acid, of Otsuchi Bay, which is a semi-enclosed bay locating on Sanriku-ria coast of Japan, subsequent to the 2011 earthquake.

【What we found】

High turbidity throughout the water column following the earthquake lasted until at least September 2011. In the high-turbidity period, high concentrations of nitrite and silicic acid compared with those in the corresponding period of before the earthquake and 2012-2015 was observed, whereas no remarkable feature of other nutrients was observed.

From September 2011 to March 2012, phosphate concentrations were notably higher than those in the corresponding period after 3 years. High-phosphate water (>0.5 μM) first appeared in the near-bottom layer in September 2011. Subsequently, phosphate concentration increased in the lower part of the water column in November and then spread throughout the entire bay between January and March, except that the concentration was low in the euphotic zone in March when spring phytoplankton bloom was likely initiated.

Damage of Great East Japan Earthquake around Otsuchi bay

Length and width of Otsuchi Bay are approximately 7 and 2-4 km, respectively. The residential areas of Otsuchi town and the Unosumai area of Kamaishi city, in which about 22,000 people lived before the earthquake, are distributed along the coastal zone of the bay and the watersheds of three rivers that flow into the bay.
The tsunami in the Bay, of which maximum height reached 15.1 m, damaged to the coastal community and the societal and industrial (especially fishery-related) infrastructures of these areas. In Otsuchi town, the number of tsunami victims reached 1200. In the inundated area, approximately 6.68 km^2, about 5600 buildings collapsed. The amount of rubble in the town and the Unosumai area of Kamaishi city was 612 ktons, and 235 ktons of tsunami deposits were left on the inundated area. Until the end of summer of 2011, the inundated area and vicinity were covered with a rotting smell from tsunami deposits and rotten fish products, which were released from damaged refrigerated warehouses in the town.
(The sources of numerical statements were listed in Fukuda et al., 2015)

Severely devastated buildings and piled debris in Otsuchi Town

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The total inorganic nitrogen (ammonium + nitrate + nitrite) to phosphate (TIN/P) ratio displayed large variability during the observational period (Fig. 1). The mean TIN/P in the bay was notably low in November 2011 [5.8 ± 0.6 (n = 17)] and January 2012 [6.9 ± 0.3 (n = 17)]. The TIN/P ratio between May 2012 and March 2013 was close to the Redfield ratio (16), which is typical elemental composition of marine organisms. However, the relationship TIN and phosphate gradually became similar to that before the earthquake in the subsequent years.

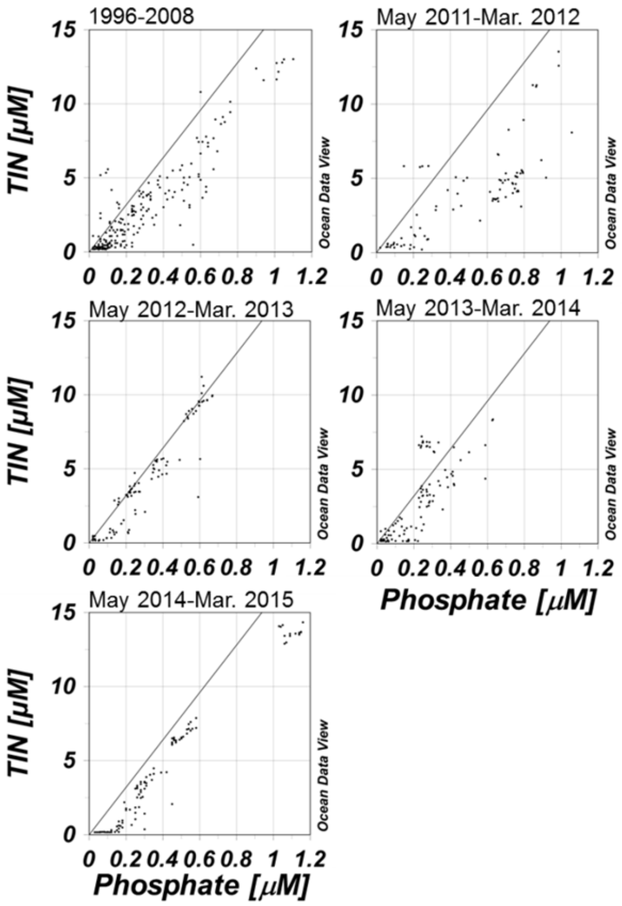

Figure 1. Relationship between TIN and phosphate for the data collected before (1996–2008) and after (May 2011–March 2012; May 2012–March 2013; May 2013–March 2014; and May 2014–March 2015) the earthquake. The Redfield ratio are indicated by the solid line.

【Conclusion】

1) Distinctive accumulations of Nitrite, silicic acid and phosphate occurred or began before the diminishment of high turbidity.
2) An increase in the TIN/P ratio during the subsequent years (2012-2013) become higher than it was before the earthquake.

Disturbance and reconstruction of the seafloor may have been one of the key processes controlling the nutrient status following the tsunami (Naiki et al., 2015), although other factors (e.g., nutrient discharge from disturbed lands surrounding the bay, fishery activities, etc.) may have also contributed to the alteration in the nutrient status.

As of the end of 2015, large-scale public works to restore infrastructure and other related changes in human activity around the bay are still in progress and they will continue for at least several years. Continuation of the monitoring of the nutrient status is necessary to provide a scientific basis for the sustainable use of the ecosystem services provided by Otsuchi Bay.

【How we investigated】

Water samples were collected from predetermined depths at four stations in Otsuchi Bay by a Niskin sampler every 2 months from 27 May 2011 to 9 March 2015. Depth profiles of temperature, salinity and turbidity were determined by CTD sensors. Concentrations of inorganic nutrient (nitrate, nitrite, ammonium, phosphate and silicic acid) were determined by calorimetry. The nutrient status of the Otsuchi Bay before the earthquake was examined using data reported in the literature (listed in Fukuda et al. (2015).

【Further readings and information】

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Some data are available at the following web site; http://www.i-teams.jp/catalog/rias/e/index.html

How did seawater quality in Ofunato Bay change after the 2011 Earthquake?

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Key words: Tsunami, Ofunato Bay, Breakwater, Nutrients, Chlorophyll *a*, Dissolved oxygen, Heterotrophic bacteria, Shellfish mariculture

【Background】

Ofunato Bay was a semi-closed area because of the breakwater effect at the entrance; however, the breakwater was destroyed by a massive tsunami generated by the 2011 Earthquake. Consequently, the physical environment of Ofunato Bay has been changed significantly, i.e., the modification of the stratified structure of seawater inside the bay and the intermittent intrusion of seawater outside the bay. These alterations of physical environment are considered to have an influence on the chemical and biological environment in Ofunato Bay.

【Aim】

To elucidate the influence of the tsunami on the aquatic environment, we measured dissolved inorganic nutrients, chlorophyll *a* and dissolved oxygen concentrations, and heterotrophic bacteria abundance inside and outside of Ofunato Bay from 2012 to 2014, and compared these data with those obtained before the earthquake.

【What we found】

As compared with before the earthquake, significant changes after the earthquake were,

(1) decrease of ammonium and phosphate concentrations
(2) increase of chlorophyll *a* concentration
(3) increase of dissolved oxygen concentration in the bottom, and
(4) decrease of heterotrophic bacteria abundance.

【Conclusion】

The collapse of the breakwater and consequential enhanced water exchange were considered to have brought the decrease of nutrient concentration inside the bay. Furthermore, washout of shellfish mariculture rafts by the tsunami decreased the shellfish biodeposits along with the elution of nutrients by heterotrophic bacteria. Decrease of cultivated shellfish further caused a decline in feeding pressure on phytoplankton and, subsequently, increased the phytoplankton biomass that contributed to the decrease of nutrients inside the bay.

Environmental features in Ofunato Bay before the 2011 Earthquake

Ofunato Bay has been damaged by tsunami many times in the past. In 1967, a huge breakwater was constructed at the mouth of the bay to prevent damage caused by tsunami. Because of the breakwater, the width of the entrance of Ofunato Bay narrowed from 850 to 200 m, and the depth of the bay entrance decreased from 36 to 16 m. The construction of the breakwater caused stagnation of water inside the bay, thereby enhancing density stratification. This stagnation of water may affect the nutrient concentration derived from terrestrial sources. Higher concentration of nutrients may increase the phytoplankton biomass, and consequential sedimentation of carcasses at the bottom of the bay; furthermore, a series of feeding and excretion activities of cultivated shellfish (oyster and scallop) promotes sedimentation of organic matter at the bottom of the bay. Decomposition of organic matter by bacteria could lead to the depletion of dissolved oxygen at the bottom layer. Depleted dissolved oxygen resulted in a confined and shallower oyster cultivation depth and a sequential decrease in the growth of cultivated oysters. The annual oyster production of Ofunato Bay decreased from 800 to 1000 tons before the construction of the breakwater to below 400 tons.

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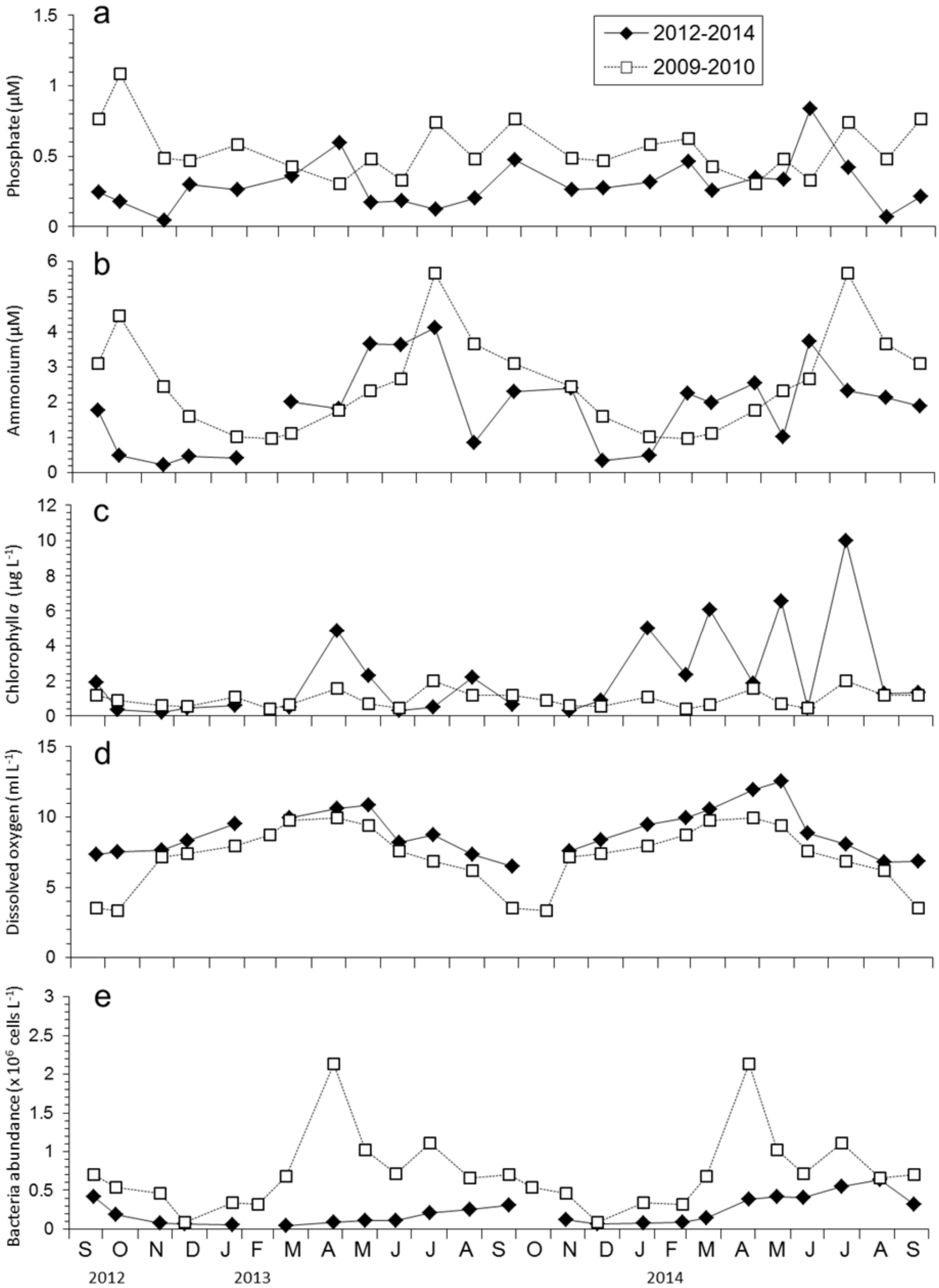

Fig.1. Comparisons of monthly variations in horizontal profiles of phosphate (a), ammonium (b), chlorophyll *a* (c), dissolved oxygen (d) concentrations, and heterotrophic bacteria abundance (e) at depth of 20 m in center of Ofunato Bay before (2009–2010) and after (2012–2014) the Earthquake

【How we investigated】

Monthly sampling was conducted from the inside and outside Ofunato Bay from September 2012 to September 2014. Vertical profiles of temperature, salinity, and dissolved oxygen were measured using a RINKO Profiler (JFE Advantec). Water samples for nutrients and chlorophyll *a* measurements were collected using a Niskin water sampler. Nutrient (nitrate + nitrite, ammonium, phosphate, and silicate) concentrations were determined using an auto analyzer (BLTEC). Chlorophyll *a* concentration was measured using a fluorescence method. Heterotrophic bacteria were stainedusing DAPI, and filtered onto a 0.2 μm filter, then photographed using a digital camera mounted on an epifluorescence under UV excitation. Heterotrophic bacteria cell numbers were counted using ImageJ software.

【Further readings and information】

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What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Marine environment in the bays of the northern Miyagi prefecture –comparision among Shizugawa bay, Ogatsu bay and Onagawa bay–

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Key words: salinity, nutrients, chlorophyll *a*, phytoplankton bloom

【Background】

The tsunami caused by the earthquake in 11 March 2011 seriously damaged facility for cultivations of scallop, oyster, seaweed which were the major fisheries industry in Tohoku coastal area. These cultivation completely depends on natural marine ecosystems. Scallop and oyster feed on natural phytoplankton, which are micro-sized algae such as diatoms and dinoflagellates. Seaweed incorporates nutrients such as nitrate, phosphate for its growth. Therefore, for developing sustainable and efficient aquaculture activity we need to understand marine ecosystems in Tohoku coastal area. The coastal area of northern Miyagi prefecture consists of various bays, which are diverse in shape and size, thus possibly having various patterns of water circulations. In addition, number and size of inflowing river are different by the bay. Therefore, there is the potential for an existence of unique ecosystem in each bay.

【Aim】

The aim of our study is to reveal characteristics of physical, chemical and biological environments in three bays (Shizugawa bay, Ogatsu bay and Onagawa bay) of the northern Miyagi prefecture by comparing the field data among the bays.

【What we found】

Temperature showed a similar temporal change in the three bays, being highest in August and lowest in March-April. On the other hand, salinity was different among the bays, especially during the period from spring to early summer, when it was highest in Shizugawa bay and lowest in Ogatsu bay (Fig. 1). Difference in freshwater supply from the land area, which might be partly caused by southward flowing of freshwater discharged from Kitakami River, might be responsible for difference of salinity among the bays.

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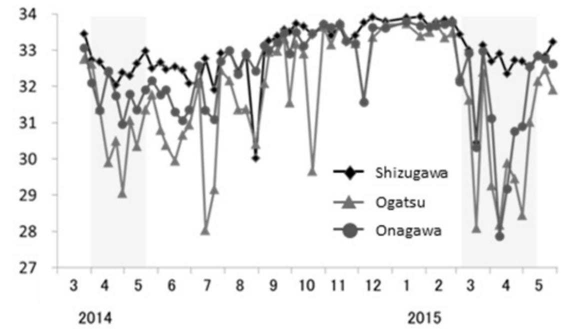

Fig. 1. Temporal change in sea surface salinity in the three bays of Miyagi prefecture. Gray area shows a period of intrusion of Oyashio water into the bay.

While nitrate varied in a similar manner in the three bays, its concentration in winter was lower in Shizugawa bay than in the other bays (Fig. 2). On the

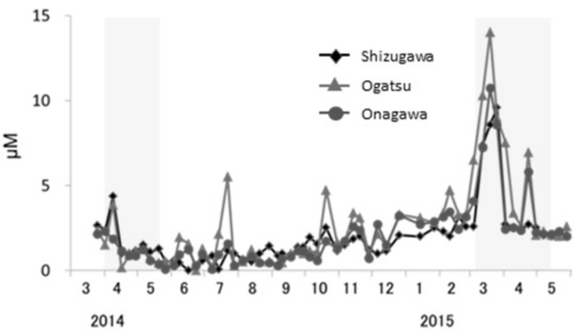

Fig. 2. As in Fig. 1 but in surface nitrate.

other hand, phosphate concentration in autumn and spring (only 2014) was higher in Shizugawa bay than in the other bays. Since freshwater discharge from the land area or intrusion the offshore water cannot explain difference of nutrient condition among the bays, nutrients elution from sediment or biological process in the water column in the bay might cause the difference of nutrient condition. Active cultivation of brown seaweed in Shizugawa bay in winter indicates that low nitrate concentration in Shizugawa bay was attributed to active incorporation of nitrate by brown seaweed.

High chlorophyll *a* concentration, i.e., phytoplankton bloom was observed mainly in response to intrusion of Oyashio water into the bay in spring in all the three bays, although it was occasionally found in summer and winter (Fig. 3). Magnitude and period of spring phytoplankton bloom was different among the bays. Spring phytoplankton bloom in Onagawa bay was larger and lasted longer than those in the other bays. Mooring observation showed that magnitude of the water intrusion into Onagawa bay was larger than that into Shizugawa bay. This indicates rich supply of nutrients from the offshore region into Onagawa bay, causing the larger and longer-lasted bloom.

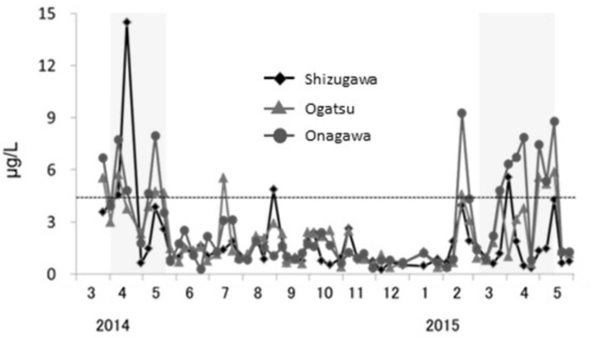

Fig. 3. As in Fig. 1 but in surface chlorophyll *a*. Dotted line shows a criterion of phytoplankton bloom. Values of chlorophyll *a* above the line mean phytoplankton bloom.

【Conclusion】

1. While temperature was similar among the three bays throughout the investigation period, salinity was different among the bays, especially during the period from spring to early summer: highest in Shizugawa bay and lowest in Ogatsu bay. Difference in supply of freshwater from the land area might be responsible for that of salinity among the three bays.
2. Nutrients condition was different between Shizugawa bay and the other bays: high phosphate concentration in autumn (and sometimes spring) and low nitrate concentration in winter in Shizugawa bay. Nutrients elution from sediment or biological process in the water column in the bay might cause the difference of nutrient condition among the bays.
3. While phytoplankton bloom occurred in all the three bays mainly in response to intrusion of Oyashio water into the bay in spring, magnitude and period of the bloom was different among the bays. Larger and longer-lasted bloom was observed in Onagawa bay. Rich supply of nutrients from offshore region into the bay due to high magnitude of water intrusion into the bay might cause the larger and longer-lasted bloom in Onagawa bay.

【How we investigated】

Sampling was conducted at dikes in the three bays of the northern Miyagi prefecture (Shizugawa bay, Ogatsu bay and Onagawa bay) basically once a week during the period from 25 March 2014 to 28 May 2015. Temperature and salinity was measured using Rinko profiler. Water samples for analysis of nutrients and chlorophyll *a* was obtained from the sea surface using a Van Dorn water sampler.

【Further readings and information】

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Changes in rocky shore ecosystems on Sanriku Coast damaged by the Great East Japan Earthquake in 2011

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Key words: tsunami disturbance, rocky shore ecosystem, kelp bed, abalone, sea urchin

【Background】

Five years have passed since the mega-earthquake “The Great East Japan Earthquake” occurred on March 11, 2011. We have been observing changes in populations of organisms living on shallow rocky reefs following the earthquake and tsunami at two different sites on the Sanriku Coast (Pacific coast of northeast Honshu Island) attacked by the tsunami; Tomarihama on the east coast of Oshika Peninsula, and Nagane in the Otsuchi Bay (Fig. 1), where regular surveys have been conducted since 2009.

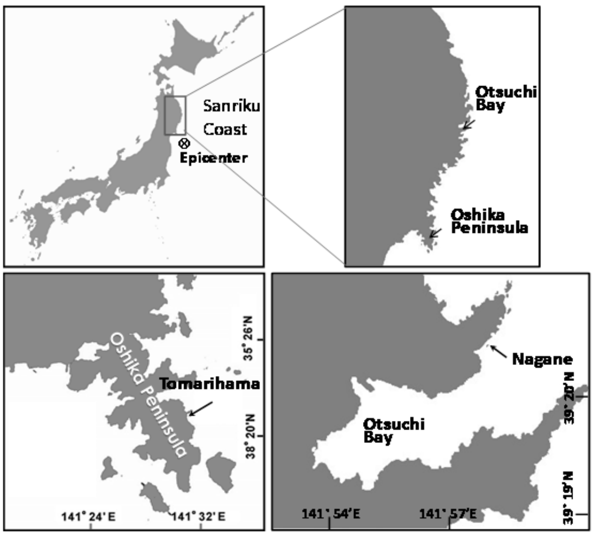


Fig. 1 Location of the two study sites, Tomarihama on Oshika Peninsula and Nagane in Otsuchi Bay, and the epicenter of the Great East Japan Earthquake.

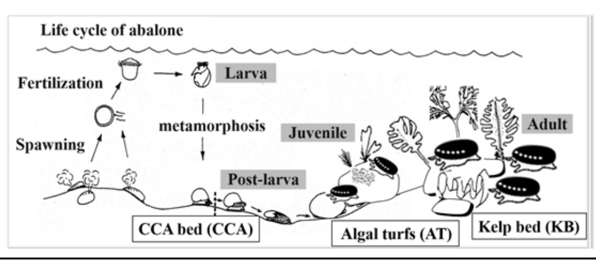
In the subtidal area at Tomarihama, a clear algal zonation mainly composed of three different macro-algal communities had been continuously observed throughout the year before March 2011: kelp beds (KB) dominated by a perennial brown macro-alga *Eisenia bicyclis* at 2 to 4 m depth, algal turfs (AT) dominated by relatively small red algae *Gelidium elegans* and/or *Pterocladiella tenuis* at 4 to 5 m depth, and crustose coralline algal area (CCA) dominated by *Lithophyllum yessoense* at 5 to 8 m depth.

Also in the subtidal area at Nagane in Otsuchi Bay, a clear algal zonation of KB at 2 to 6 m depth and CCA at 7 to 12 m depth, had been observed before March 2011. The KB was, however, dominated by another different species of an annual brown macro-alga, *Saccharina japonica* var. *religiosa*. This kelp species starts growing between April and May and forms dense communities on rocky reefs, but dies to flow out from October to November, remaining only holdfast part. Therefore, the clear algal zonation can only be seen between April and November. CCA was dominated by *Lithophyllum yessoense* as same at Tomarihama. Algal turfs dominated by small red algae were found in and around the kelp forest, but did not form clear independent zonation AT at Nagane.

In Otsuchi Bay, another monitoring transect survey on the abundance of the abalone has been carried out since 1994, on nine fixed lines in the inner, middle and entrance part of the bay along the western and southern coasts.

Ontogenetic habitat shift in the abalone and the sea urchin

The abalone *Haliotis discus hannai* changes the major habitat as it grows. The swimming larvae selectively settle on the CCA bed to metamorphose into crawling juveniles. Juveniles live on the CCA bed for a year or more, then move to AT as the transitional habitat, and to the final habitat KB when they grow up to 4 - 5 cm SL (Won et al. 2010). While juvenile and adult urchins inhabit CCA and AT throughout their life and do not move into the KB, although the swimming larvae of the urchin selectively settle on the CCA bed to metamorphose into crawling juveniles as same as the abalone larvae.



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【Aim】

Changes in the shallow rocky shore ecosystems since the tsunami and other events associated with the earthquake are studied and compared between the two sites, Tomarihama on the Oshika Peninsula and Nagane in Otsuchi Bay. We especially focused on the abalone *Haliotis discus hannai* and sea urchin *Strongylocentrotus nudus* (Fig. 2) populations, which are economically important fishery resources in the area, and also play important roles in the food web of the rocky shore ecosystem (Won et al. 2013).

Changes in the densities of the abalone along the survey lines were compared among locations inside the Otsuchi Bay.

Fig. 2. The adult abalone *Haliotis discus hannai* in the Kelp bed dominated by *Saccharina japonica* var. *religiosa*, and the sea urchin *Strongylocentrotus nudus* on the rocky reef in Otsuchi Bay.

【What we found】

Effects of the tsunami on rocky reefs were more obvious at Tomarihama than at Nagane in Otsuchi Bay. Many of the large rocks were cracked and rotated on the sea floor at Tomarihama, while such apparent evidences of disturbance were not observed at Nagane. However, no apparent effects were observed on the kelp beds at both study sites (Kawamura et al. 2014).

At Tomarihama, both adult and juvenile abalone were apparently affected by the tsunami disturbance (Takami et al. 2013), while at Nagane, juvenile abalone < 4 cm SL appeared to be more seriously affected by the tsunami than adults. Sea urchin densities largely decreased both at Tomarihama and Nagane, indicating that urchins were more severely impacted by the event compared with abalone. Sea urchin density remained low level during 2 years since the event at Tomarihama, while recovered to be almost the same level before the tsunami within 6 months from the event at Nagane (Kawamura et al. 2014).

On the western and southern coasts of Otsuchi Bay, decreases in abalone density were larger along three lines located in the inner part than those in the middle and entrance parts of the bay. Abalone densities in the inner part of the bay were still in a low level 4 years after the tsunami.

【Conclusion】

1. Effects of the tsunami on the rocky reef are likely to vary largely on location and shape of coastline even in a bay.
2. Different species and growth stages of organisms had different effects by the tsunami even in the same ecosystem, the rocky reef.
3. Benthic organisms attaching weakly to the bottom substrates (e.g. sea urchin *S. nudus* and juvenile abalone *H. discus hannai*) had more serious impacts than strongly attached organisms (e.g. adult *H. discus hannai*).
4. Organisms inhabiting exposed areas (e.g. *S. nudus* and juvenile *H. discus hannai*) had more effects than those inhabiting perennial kelp forests (e.g. adult *H. discus hannai*), where the current velocity of the tsunami might be attenuated by the presence of the algal canopy.
5. Although the damaged populations have started recovering and/or adapting to the new environment, the speed and process in changing are different among organisms and areas.

【Further readings and information】

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Sessile organisms in Otsuchi Bay and Matsushima Bay after the Great East Japan Earthquake and Tsunami

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Key words: sessile organisms, bryozoa, seasonality, settlement panel, dredge, ROV

【Background】

Sessile organisms attach to various substrates, such as rocks, bivalves, algae, and fishing tools. In the field of fisheries, sessile organisms are well known as fouling organisms. Furthermore, most of the sessile organisms such as barnacles and bryozoans are filter feeders; therefore, they are also known as competitor to cultured oysters, scallop, and ascidian. On the other hand, as in the example of coral reefs, sessile organisms play various important roles in the marine benthic community. Bryozoans are known as one of the members which contribute to the structure of the benthic community, especially in the temperate zone. Bryozoans are providing a habitat and food for other organisms such as molluscs, crabs, sea urchins, and fishes. After the Great East Japan Earthquake and Tsunami, most of the cultured facilities were heavily damaged along the Pacific coast of Tohoku; it causes increasing of food resources for filter-feeders. However, the effects of the earthquake and tsunami in sessile organism assemblage are still unknown.

【Aim】

In this study, sessile organism fauna and their seasonality in Otsuchi Bay and Matsushima Bay were surveyed to see the effect of the tsunami and the restoration from the disaster, with particular focus on the bryozoan assemblages (Fig. 1).

Fig. 1 Map showing the surveyed localities.

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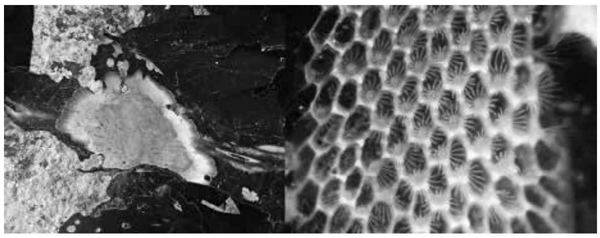
What is Bryozoa?
Bryozoans (moss animals) comprise a phylum of sessile, modular, clonal animals, in habiting marine and freshwater environments. Bryozoans form colonies of various morphologies on many kinds of substrate such as rock, algae, and shells. The zooids in a colony have a feeding organ called lophophore, with ciliated tentacles surrounding the mouth. The zooids feed phytoplankton using the lophophore. Bryozoans occur in all oceans, from the intertidal zone to abyssal depths. About 6000 living species have been described, and about 20000 species overall, including fossil species. Fossil bryozoan species are known from the early Ordovician and are abundant in the Paleozoic. Because of the long fossil record, high diversity, broad distribution, and important roles in sessile communities, bryozoans have attracted considerable attention from marine ecology, paleoecology, and environmental science.



【What we found】

On settlement panels in the bay

Biomass of sessile organisms tended to increase after tsunami in Otsuchi Bay and Matsushima Bay. In Otsuchi Bay, barnacles were remarkably abundant during summer, and encrusting bryozoans (e.g., *Pacificincola* sp. and *Electra* sp.) and colonial ascidians were dominant during winter. In contrast, amount of bryozoan colonies on the settlement panels was highest during summer to autumn in Matsushima Bay; flexible erect species (e.g., *Bugula neritina* and *Amathia* sp.) were especially abundant (Fig. 2). Bryozoan biomasses in these bays were especially high in the area affected by river water and in the depth of high chlorophyll values.

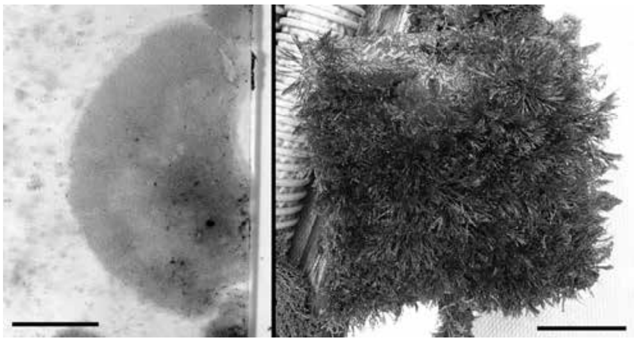


Fig. 2 Bryozoan colonies on the settlement panel in Otsuchi Bay (Left, scale bar 2 cm) and Matsushima Bay (Right, scale bar 5 cm).

Shallow rocky habitat

We found more than 50 species of bryozoans at near shore rocky habitats in Otsuchi Bay. In the inner part of Otsuchi Bay, we found numerous flexible colonies of erect bryozoans on rocky bottom in 20 m deep, at the southern part of Hourai-jima. We obtained two species from the rocky bottom; *Microporina japonica* Canu & Bassler, 1929 and *Alcyonidium sagamianum* Mawatari, 1953 (Fig. 3). The former species was described from the Tsugaru Strait, and the latter was from Sagami Bay. *Alcyonidium sagamianum* was also reported from near Hourai-jima in Otsuchi Bay more than 30 years ago (d'Hondt and Mawatari, 1986).

Fig. 3 Living colony of *Alcyonidium sagamianum* found in 2015 (Left, scale bar 3 cm) and the preserved specimen collected from Otsuchi Bay in 1983 (Right).

Deep rocky habitat

We found a large amount of robust erect bryozoan colonies of *Celleporina* sp. in 90 m deep at the entrance of Otsuchi Bay. This species was collected from the same locality before the earthquake. Some of the large living colonies of *Celleporina* sp. are estimated as more than 5 years old based on the growth band in the sectioned branch (Fig. 4).

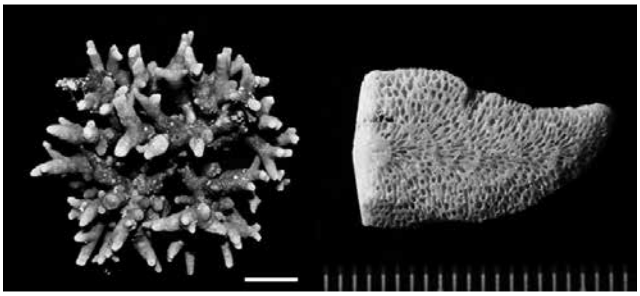


Fig. 4 Colony of *Celleporina* sp. collected from the entrance of Otsuchi Bay (Left, scale bar 3 cm) and the sectioned branch (Right).

【Conclusion】

1. Amounts of sessile organisms were increased in Otsuchi Bay and Matsushima Bay after the tsunami disturbance; their distribution is seems to be correlate with the abundance of food resources for filter-feeders.
2. Some short living bryozoan colonies such as *Alcyonidium sagamianum* have already recovered from the damage after the effect of the Great East Japan Earthquake and tsunami, at near shore rocky habitat in Otsuchi bay.
3. Some of the large colonies of *Celleporina* sp. inhabiting the entrance of Otsuchi Bay could survive through the earthquake and tsunami.
4. Further analyses of the calcium carbonate skeleton of the survived bryozoan colony will reveal the effect of the earthquake and tsunami to the bryozoan assemblage more in detail.

【How we investigated】

Seasonality of sessile organism in Otsuchi Bay (from 2013 to 2014) and Matsushima Bay (from 2014 to 2015) was surveyed by using mooring settlement panels. Water temperature and light intensity at each depth for the panels were recorded by the Pendant Temperature/Light Data Logger (Onset, HOBO Data Logger). The other environmental factors such as temperature, salinity, and chlorophyll value were measured by CTD.

Specimens from the entrance of Otsuchi Bay were collected by fisherman net in January 2012. Additional specimens were collected by dredge on research boat "Yayoi" in August and October, 2014.

Specimens from the southern part of Hourai-jima were collected by Remotely Operated Vehicle (ROV) (VEGA, Kowa Co., Ltd) operated by the International Coastal Research Center in March, 2015.

Specimens were observed by light microscope at the Atmosphere and Ocean Research Institute (AORI).

What happened to the marine environments after Great East Japan Earthquake？
TEAMS International Conference, March 2016

Rocky intertidal zonation: impacts and recovery from the megaquake

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Key words: benthos, distribution, rocky intertidal, Sanriku, seaweed, subsidence, tsunami, zonation

【Background】

2011 Great East Japan Earthquake caused a large tsunami and massive subsidence over the entire Tohoku region. As with all coastal communities, rocky intertidal communities may have suffered heavy damage. This is because organisms in this habitat may be damaged not only by the tsunami but also by subsidence. Distributions of most rocky intertidal species are restricted to within a narrow vertical range of several tens of centimeters, suggesting that rocky intertidal organisms, especially sessile species, will be greatly affected by land-level changes over only a small vertical range.

In rocky intertidal habitats, zonation is the most general spatial distribution pattern of organisms. The mega-earthquake would immediately alter the zonation of each species through the direct effect of the tsunami and subsidence; thereafter, there could be additional changes in zonation via modification of population processes after the earthquake, such as mortality and recruitment. In addition, the immediate impacts of the earthquake and subsequent changes in zonation should vary among species. Although Castilla (1988) described the impact and recovery of rocky intertidal zonation from the uplift associated with a megaquake for a single sessile species, there are no studies yet concerning the impact and recovery from an earthquake and associated subsidence except for qualitative evaluations of changes in position of zonation of sessile organisms (Haven 1972, Johansen 1972).

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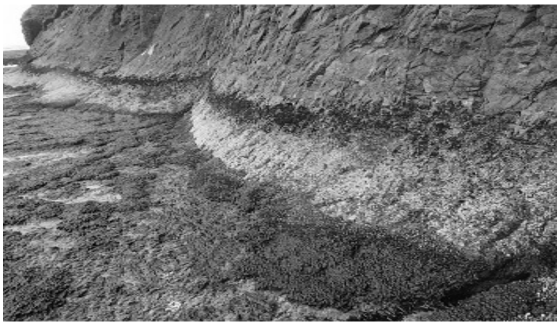
What is rocky intertidal zonation?

Zonation is a striking pattern of organismal distribution which is generally found in intertidal rocky shores. Rocky intertidal zonation is a distinct horizontal band of specific species at each elevation. The upper and lower limits are often determined by desiccation stress and species interaction (predation and competition), respectively.



【Aim】

To assess the course and status of recovery of rocky intertidal zonation of 10 dominant macrobenthic species (6 sessile and 4 mobile species) along the Sanriku coastline, 150–160 km north-northwest of the earthquake epicenter, within 4 years after the mega-earthquake.

【What we found】

The dynamics of rocky intertidal zonation varied substantially among species (Fig. 1). Among 6 sessile species, one barnacle dramatically increased in abundance and expanded its vertical range in 2011, but then decreased and completely disappeared from all survey plots by 2013. Zonations of other 5 sessile species shifted downward following the subsidence in 2011. With 3 species, there was no clear change in abundance immediately after the earthquake, but

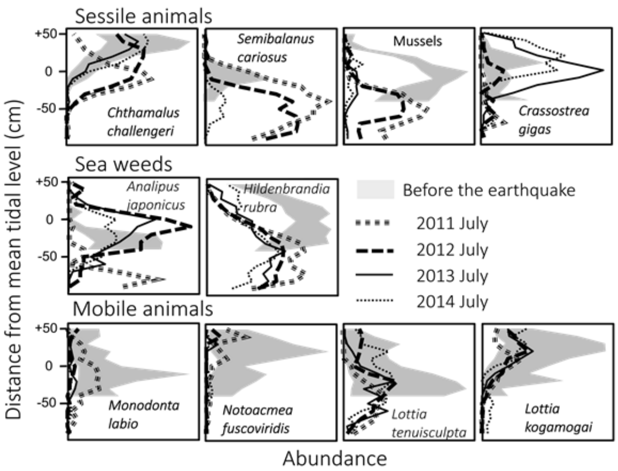


Fig.1. Course and status of recovery of rocky intertidal zonations of 10 dominant macrobenthic species (6 sessile and 4 mobile species) along the Sanriku coastline, 150–160 km north-northwest of the earthquake epicenter, within 4 years after the megaquake. Abundance at each tidal level were calculated using data accumulated from all plots. Abundance before earthquake at each tidal level indicates mean ± 1.96 standard deviation of data obtained from each census of pre-earthquake period (2003–2010).

they then began to increase and move upward after a few years; with other 2 species (late-successional taxa), abundance continuously decreased. There was no clear change in the vertical distribution of any of the mobile species immediately after the earthquake. Abundance of 2 mobile species was unchanged, but abundance of the others decreased from 2012 and had not recovered as of 2014.

【Conclusion】

1. The 2011 Great East Japan Earthquake significantly altered rocky intertidal zonation along the Sanriku Coast 150–160 km north-northwest of the epicenter of the earthquake, mainly as a result of coseismic subsidence rather than the tsunami.
2. Four years after the earthquake, the zonation of late-successional sessile taxa had not recovered, suggesting that the rocky intertidal community will experience a long delay in recovering from the effects of the earthquake.
3. The dynamics of rocky intertidal zonation after the earthquake and accompanying subsidence includes two unique features: a delayed negative impact, and an occasional increase in population sizes of several taxa. Neither of which has been reported following earthquakes of similar magnitude with accompanying uplift, in which there were mass mortalities of zone-forming species within one year after the event, preceding downward shifts in their zonations (Haven 1972, Johansen 1972, Castilla 1988).

【How we investigated】

We censused the vertical distribution of 10 dominant macrobenthic species (6 sessile and 4 mobile species) at 4,16,28 and 40 months after the megaquake in the mid-shore zone of 23 sites along the Sanriku coastline and compared the vertical distributions of each species with their vertical distributions in the pre-earthquake period (2003–2010).

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What happened to the marine environments after Great East Japan Earthquake?
TEAMS International Conference, March 2016

Recoveries of the tidal flat ecosystems after the 2011 earthquake and tsunami

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Key words: macrozoobenthos, community structure, tidal flat, Gamo Lagoon

【Background】

A megathrust earthquake that measured 9.0 on the Moment Magnitude Scale occurred off the Pacific coast of northeastern Japan on March 11, 2011. Huge tsunami waves struck the intertidal soft bottoms and not only have changed the topography of the tidal flats but also have severely damaged the benthos that lives in association with the sea bottoms. It is important to monitor the changes of marine environmental factors and benthic community to understand the impacts of the earthquake and tsunami on tidal flats. We had chance to investigate the macrozoobenthos in Gamo Lagoon and other tidal flats nearby after the earthquake and tsunami. Gamo Lagoon (0.11 km^2, mean water depth 0.8 m) is located on the north side of the Nanakita River Estuary (38˚N, 141˚E) in Sendai Bay, Japan. The lagoon is separated from the estuary by a stone levee with water gates, and from Sendai Bay by a 150-m wide sand bar.

【Aim】

To see the changes of the numbers and structures of macrozoobenthos community in Gamo Lagoon and other tidal flats, and understand the impacts of the earthquake and tsunami and subsequent disturbance events on the tidal flats ecosystem.

【What we found】

Structure of macrozoobenthos community and its dynamic were different between each tidal flat in the coast of Tohoku District.

Drastic topographical changes have repeatedly been observed in Gamo Lagoon until today. Just after the tsunami, the sand dune disappeared through intensive scouring and deposition of drifting sea sand; in August 2011, the river mouth was closed completely by deposited sea sand; in September, the bottom sediment near the floodway were washed away by a seasonal typhoon-induced flood; a new small river mouth was opened after the flood; a river mouth was re-opened at the previous position through construction. Following drastic topographical changes, structure of the macrozoobenthos community kept changing. The density of the macro-zoobenthos largely decreased just after the disturbance, and only characteristic spionid annelids and amphipods were observed. However, one month later, small sized annelid worms drastically increased suggesting that they recruited by newly settled population. According to the typhoon-induced flood occurred in September, the density again decreased, and after the construction of a new river mouth, the

What are the tidal flats?

The tidal flats are intertidal soft sediment habitats, located generally in estuaries and other gradual slopes distributed widely along coastlines world-wide. These habitats are of great importance to large numbers of invertebrates and fish and providing resting and feeding areas to indigenous and migratory birds. There are many kinds of animals which live wholly or partly within the substrate and we can see many bivalves, annelid worms as well as other small invertebrates. These macrozoobenthos have little ability to migrate and their lives largely depend on bottom environment. Bottom soft substrates are often very fragile and they may easily be disturbed physically by various events such as seasonal typhoon and flood, and unusual big earthquake and tsunami can drastically change the bottom environment. The tidal flats play an important role not only as habitats of many marine organisms but in recycling organic matters and nutrients from both terrestrial and marine sources, decomposition, biological productivity, and biodiversity.

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density of the macrozoobenthos gradually observed to increase to the previous level. The increase of bivalves was drastically observed in summer of 2012 and they occurred continuously from that time on. It was hypothesized that the recruitment of bivalves in 2011 was prevented by river moth closing and typhoon-induced flood disturbances. Structure of macrozoobenthos community was different between (1) each station (space) and (2) each sampling date (time).

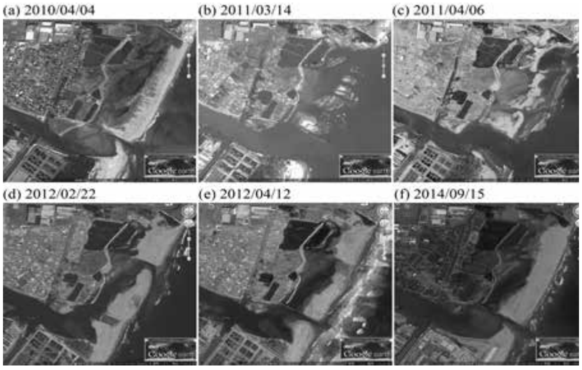

Fig. 1. Topographical changes in Gamo Lagoon.

【Conclusion】

1. The macrozoobenthos in Gamo Lagoon may still be in the process of recolonizations, almost three years after the earthquake and tsunami disaster.
2. The long-term data sets used to evaluate community succession, following earthquake and tsunami, have been an invaluable resource. Monitoring should be continued.

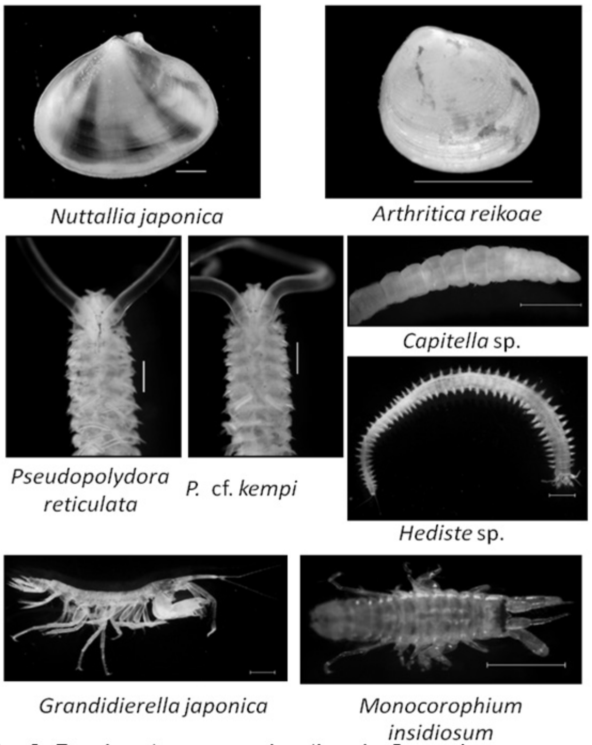

Fig. 2. Dominant macrozoobenthos in Gamo Lagoon.

【How we investigated】

The macrozoobenthos was sampled at several stations each month from May, 2011. Sediment was collected by core sampler and was sieved through a 500 μm mesh sieve, and all animals remaining on the sieve were fixed with 10% neutralized formalin. In the laboratory, all the animals were sorted, identified and counted under a stereomicroscope. Water temperature, salinity, and dissolved oxygen (DO) concentration were measured.

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What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Short-term and long-term effects of the 2011 earthquake on intertidal mollusks

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Key words: bivalve, tidal flat, earthquake, tsunami, liquefaction, subsidence, disturbance

【Background】

Little is known about the effects of the 2011 earthquake and subsequent tsunamis on intertidal mollusk species. Before the earthquake, I conducted a series of field surveys in Tohoku district, northern Japan to examine ecological impacts of the invasive moon snail *Euspira fortunei* (*Laguncula pulchella*) on commercially important clams and endangered bivalves (Okoshi 2004).

【Aim】

What was happened on the benthic community during the period from just after the earthquake to just before arrival of the tsunamis? I focused primarily on bivalves that inhabit the sandy and muddy intertidal zone, and described short-term effects of the earthquake through the subsequent liquefaction and tsunamis and long-term effects through the land subsidence on the bivalve populations.

【What we found】

At 14:46 p.m, at the time of the earthquake, I was standing on Yatsu tidal flats in Tokyo Bay. The sandy flats were exposed at the maximum neap low tide. During the earthquake, sediment surface of the tidal flats moved in a wavelike fashion. The ducks and gulls on the tidal flat took flight and then landed once the earthquake had subsided. These birds were not able to predict the earthquake in advance. Liquefaction occurred just after the earthquake before the arrival of the tsunami. Liquefaction is a phenomenon where the strength and stiffness of a soil are weakened by earthquake shakings. Water spurted from cracks in the soil, which looked like a jet fountain. There were many sand boils that erupted on the tidal flats around the Sanbanze tidal flats near the Yatsu tidal flats after the earthquake (Okoshi 2012, 2015). It is thought that this was caused by ground liquefaction.

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Bivalves which are normally distributed in deep mud, were dug out by the jet water from the deep sediments in Gamo tidal flats in Miyagi Prefecture, northern Japan during liquefaction (from the Kahoku Shinpo article of August 25, 2011). Thus, many bivalves inhabiting submerged sediments might have been brought out to the sediment surface before the arrival of tsunamis and then swept away by the tsunamis (Okoshi 2015, in press).

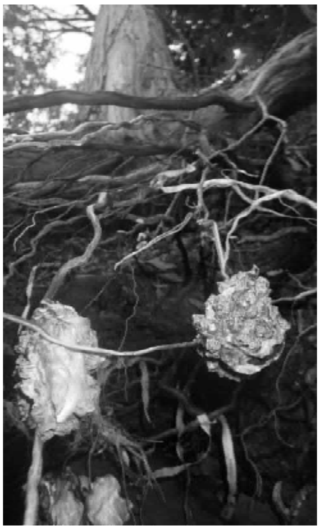
Owing to the distance of the earthquake's epicenter from Japan, there was no effect by liquefaction and land subsidence mentioned after along the coast of Japan by the massive earthquake that occurred in Chile in 1960. The separate impacts of earthquakes (liquefaction and land subsidence) and tsunamis have often been confused with respect to their influence on marine life, but it is necessary to consider each separately (Okoshi in press).

Tsunamis seemed to displace many sub-tidal organisms to the land. The Purple Washington Clam *Saxidomus purpurata*, that inhabit the sandy subtidal zone, was washed away toward inland by the large waves of the tsunamis (Okoshi 2012). The horse mussel *Modiolus kurilensis* was also left at inter-super tidal zone with rocks that they attached with byssus threads. As such, the tsunami waves took temporally marine organisms originally live in subtidal zone to inter- and super tidal zones. On the other hand, undertows of the tsunamis seemed to push intertidal and subtidal organisms away to the deep sea. In this way, marine organisms that were displaced inland died, while those swept into deeper waters seem to have a greater chance of survival (Okoshi in press).

The tsunamis affected indirectly benthic organisms by destroying or re-distributed benthic substrate. There are few firm basis for attachment of oyster larvae in intertidal mud flats. The Japanese or Pacific oyster *Crassostrea gigas* is one of the reef-building oysters. Huge oyster reefs that were developed at the mouth of the Matsukawaura Lagoon were destroyed by the tsunamis and pieces of the reefs were spread around in the muddy and sandy lagoon (Okoshi in press). New oyster reefs have then formed on these pieces after the tsunami. For the past 3,500 years, massive earthquakes like the Great East Japan Earthquake in 2011 occurred at least seven times (source: The Japan Times News, Jan. 27, 2012). Repeat massive tsunamis might have contributed to allow sessile organisms including oysters and barnacles to explore a new habitat (Okoshi in press).

Land subsidence means the disappearance of intertidal zone. It is not yet clear how sudden occurrence of land subsidence damage marine organisms. At Mangoku-ura Lagoon, Miyagi Prefecture, land subsidence of ca.80 cm was observed after the earthquake and the shoreline backed away and the intertidal zone became to subtidal zone. The impact of land subsidence was apparently severe for sessile organisms compared with mobile organisms.

Mangrove tree?
Due to the land subsidence, roots and trunk of cedar trees originally grown along shoreline sunk below the seawater and were used as settlement substrata by larval oysters and barnacles.



Juvenile oysters found at intertidal zone where had been supratidal zone. Thus, adult and juvenile oysters did not been unusually overlapped their distribution zones in growing season of 2011 (Okoshi in press).

The snails *Littorina brevicula* and *Batillaria cuming*i, which are mobile benthic organisms, were found on the shores that were previously land before the earthquake (Okoshi 2012). The fact showed that these species colonized promptly the newly formed intertidal zones after the earthquake. It is expected that these newly-formed intertidal zones may be environmentally unstable, and change continually and gradually the physical and chemical conditions such as particle size composition, salinity and nutrient supplies due to meteorological events like typhoon and anthropogenic activities (Okoshi in press).

According to our field surveys in Mangoku-ura Lagoon for three years after the earthquake, species composition and abundance of bivalves changed every year, indicating that the bivalve community was compositionally unstable. It is essential to monitor these organisms continually to uncover long-term effects of the land subsidence caused by earthquake on aquatic organisms (Okoshi 2015, in press).

【Conclusion】

Long-term monitoring is needed to evaluate the impacts of not only Great East Japan earthquake but also those of disaster prevent structures constructed along the shorelines on the marine organisms.

【How we investigated】

Study term: Monthly intervals from May 2011 to April 2014. Procedure: Surface sediments collected using $1m^2$ or $50cm^2$ square quadrats, and were washed through a 1-mm aperture mesh sieve.

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The genetic disturbance caused by the mega-tsunami on a coastal species

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Key words: *Batillaria attramentaria*, genetic structure, local population, mega-tsunami

【Background】

A mega-tsunami has a big influence on benthic organisms inhabiting the coastal area as it causes extinction or decline in the local population. Additionally, it is thought that such a great disturbance decreases genetic diversity and changes genetic structure of local populations in the tsunami-hit area. In order to clarify the impact on benthic organisms of a tsunami, it is necessary to compare the genetic diversity and structure of the local populations before and after the tsunami. Intertidal mud snail *Batillaria attramentaria* (= *B. cumingi*) predominates in the coastal area of the Tohoku district, Japan, and genetic information of its local populations had been analyzed before the Great East Japan Earthquake in the previous studies. Along the Sanriku coast, *B. attramentaria*, which is a direct-developing species showed a complicated genetic structure as a result of its low dispersal ability and intricate coastline of rias (Fig. 1). We thought that *B. attramentaria* is ideal for understanding the impact of the recent mega-tsunami on the benthic organisms.

Genetic structures of marine organisms around Japan

In previous study which was based on a mitochondrial gene, individuals of *Batillaria attramentaria* showed to be composed of two genetically distinct groups which are distributed corresponding to the routes of two warm currents, respectively (Fig. 1). Around Japan, similar geographically genetic structures have been reported from some other marine organisms which have low dispersal ability, for example, the forktongue goby, the black lined limpet, and the ice goby. It was considered that such genetic structures have been formed by geographic isolation of local populations related to historical events such as climatic and geomorphological changes.

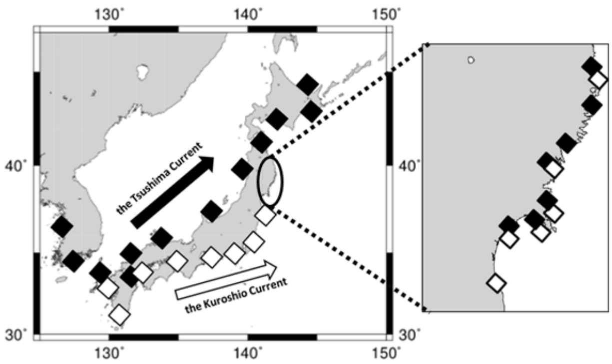

Fig. 1. Genetic structure of local populations of *Batillaria attramentaria* around Japan. Closed and open diamonds represent distinct genetic groups corresponding to the warm currents, respectively.

【Aim】

To elucidate the change of the genetic structures of local populations of *B. attramentaria* associated with the 2011 mega-tsunami.

【What we found】

By the analysis based on the mitochondrial cytochrome *c* oxidase subunit I (COI) gene, a decrease of genetic diversity and a change of the genetic structure were showed in some local populations (Fig. 2). After the Great East Japan Earthquake, drastic decrease of the individual was observed in the local population in Hitsugaura as well as Matsushima Bay where a change of the genetic structure was detected. These changes might be attributable to the genetic drift caused by the tsunami. However, such change was not detected by the analysis of simple sequence repeat (SSR) loci. Two distinct genetic markers, mitochondrial COI gene and SSR loci, are different in the hereditary mode, namely, maternal and parental, respectively. Due to this

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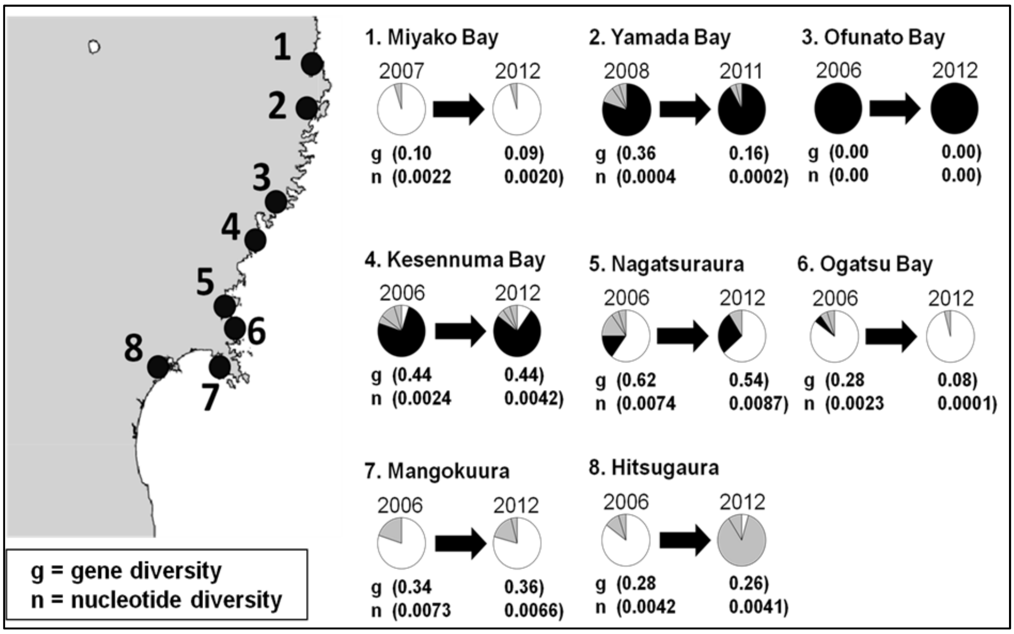

Fig. 2. Changes of genetic structure in local populations of *Batillaria attramentaria* in the study area before and after the Great East Japan Earthquake. Pie graphs show frequencies of individuals which have unique nucleotide sequences. Black and white represent major sequences which are genetically distinct respectively, and gray is others.

difference, the time it takes for these two makers to reveal influences of the disturbance might be different.

【Conclusion】

Some local populations of *B. attramentaria* were shown to have genetically disturbed by the mega-tsunami associated with the Great East Japan Earthquake. The influence of the disturbance might appear earlier in mitochondria than in chromosomal genes. Continued monitoring of genetic structure of this species is important to understand the genetic disturbance by the mega-tsunami and the recovery process in the coastal communities.

【How we investigated】

Total DNA was extracted from the head‐foot region of *Batillaria attramentaria* individuals which were collected from 8 local populations in the range from Iwate to Miyagi prefectures, before and after the Great East Japan Earthquake. Using the ABI 3130 capillary sequencer (Applied Biosystems), we determined nucleotide sequences of mitochondrial COI gene and polymorphism of SSR loci on chromosomes for approximately 20 individuals from each population per each sampling year. The obtained genetic data of each local population were compared before and after the Great East Japan Earthquake.

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Distribution of the Manila clam, *Ruditapes philippinarum,* and physical environmental conditions in the Natori River estuary in northeastern Japan after the Great Tsunami

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Key words: Manila clam, Estuary, Physical environment, Tsunami

【Background】

Miyagi Prefecture is the second largest fishery landing region in Japan. The Natori River estuary is an important fishing ground for both bivalves and fishes. Especially the Manila clam *(Ruditapes philippinarum)* is a resource of commercially valuable bivalve in the Natori River estuary in northeastern Japan. The Great East Japan Earthquake and tsunami in March, 2011, resulted in ground subsidence, deposition of rubble and mud. Severe morphological changes occurred in the coastal area and river mouth.

【Aim】

To clarify the relation between population status of the Manila clam and environmental conditions in the fishery ground, and to reconstruct the fishery of this clam, surveys have been proceeding.

【What we found】

The manila clam population in the Natori River recovered temporarily in 2012: many juveniles were collected. However a marked reduction in the population was recorded after heavy rainfall in the summer of 2013. Lots of empty shells of manila clam were collected.

In contrast, the population density of another clam species, *Nuttallia olivacea*, has returned to approximately the same level as before the tsunami. This bivalve is a euryhaline species, which inhabited the same region in the Natori River estuary as *R. philippinarum* before the tsunami (Fig.1).

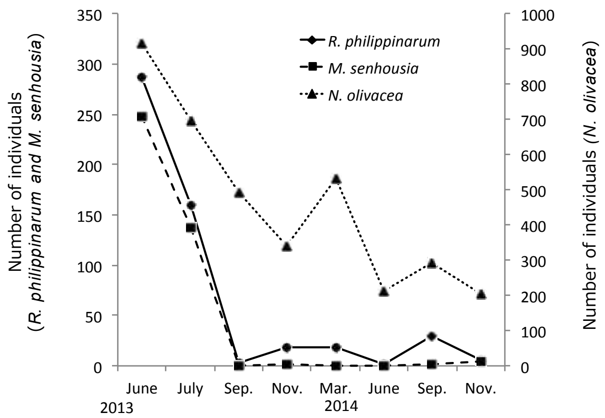

Fig.1 Total number of individuals of dominant bivalves caught in the Natori River estuary in 2013 and 2014

Great topographical changes, especially the formation of sand spit intrusions into the river, have reduced the width of the river mouth (Fig. 2)

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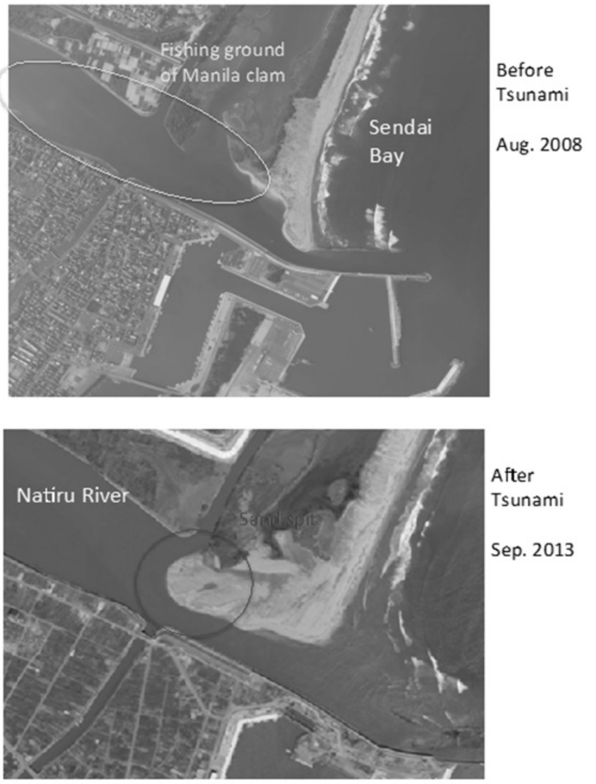

Fig.2 Topographical changes, especially the formation of sand spit intrusions into the river, have reduced the width of the river mouth

Heavy rain and dam discharge induced a longer retention time for fresh water within the river. The data logger recorded salinity as low as 0 psu during flood tides (Fig. 3). Heavy rain and dam discharge to relieve high reservoir levels have induced longer periods of fresh water detention in this part of the river.

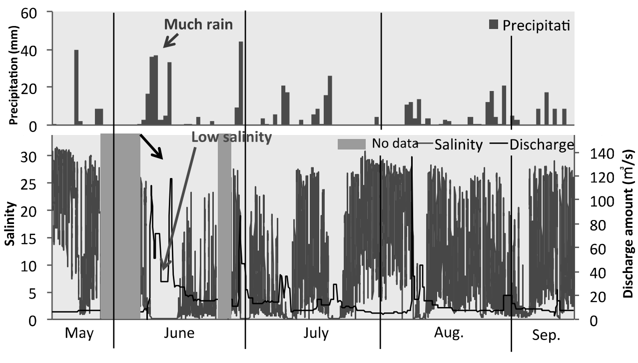

Fig. 3 Daily precipitation in Natori City (top) and relationship between salinity fluctuation and discharge amount from Kamafusa dam (bottom)

It is suggested that low salinity has prevented the recovery of the Manila clam population.

【Conclusion】

Manila clam recruitment has not yet occurred successfully since the tsunami. It is suggested that low salinity has induced the damage to the manila clam population.

MLIT of Japan begins to remove the sand spit to recover environmental condition of the Natori River estuary from June 2015.

【How we investigated】

Field surveys were conducted at 18 sampling sites on the 6 lines in the Natori River Estuary. Population density was estimated based on a quadrat (0.3 x 0.3m) method.

To understand accurate diurnal changes in salinity and temperature, data-loggers have been installed in the river. Bottom sediments are also collected and analyzed at regular intervals.

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What happened to the marine environments after Great East Japan Earthquake？
TEAMS International Conference, March 2016

The immediate impact of the tsunami on ayu *Plecoglossus altivelis altivelis* population in Sanriku region

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Key words: amphidromous fish, migration, otolith, *Plecoglossus altivelis altivelis*, Sr:Ca ratio

【Background】

The ecological impact of the tsunami on coastal environment has intensively been investigated. In those researches, it was reported that the fishes or benthic animals disappeared or decreased its number after the tsunami associated with changes in the seafloor and coastal topography. Therefore, it can be expected that the tsunami could also affect the migratory fishes, which move between the sea and the river within their life.

Ayu *Plecoglosses altivelis altivelis* is popular amphidromous fish in Japan and is one of the most studied migratory fish. Ayu is also an important fishery resource as an edible fish and for the recreational fishing. Ayu has an amphidromous life history with 1-year longevity, in which they spend their larval and juvenile life in the sea (Fig. 1). The larvae hatch in autumn to winter and immediately drift down to the sea, and migrate into the river next year after growing in the sea. The tsunami has destructed the juvenile coastal habitat such as surf zone and estuary. Therefore, it was expected that the tsunami disturbed the ayu populations. We have performed the ecological study of ayu at the rivers in the Sanriku region since before the tsunami, so it is possible to detect the ecological changes after the tsunami.

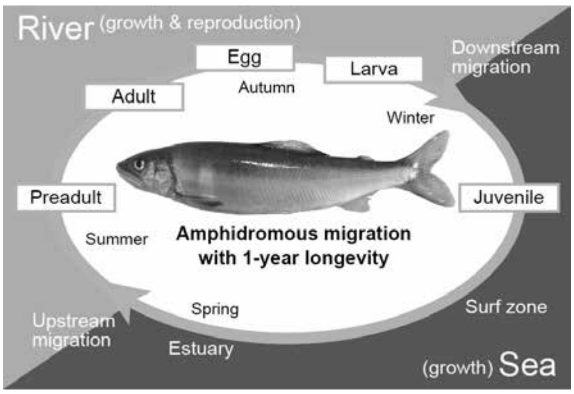

Fig. 1 General life history of ayu.

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【Aim】

The aim of this study was to clarify the immediate impact of the 2011 tsunami on the local population of ayu in the Sanriku region.

【What we found】

Our research showed that the tsunami drastically altered the ecology of ayu. First, hatching date composition of upstream migrants was shifted significantly later in 2011 in the Unosumai and the Sakari RIver (Fig. 2). The 2011 migrants were completely composed of late-hatched fishes (hatched in October and November), whereas early-hatched fishes (hatched in September) mainly constituted 2010 migrants. However, based on the seasonal changes in the amount of drifting larvae, it was expected that early-hatched fishes would have dominated in 2011 as in 2010. This discrepancy suggested that there was a selective mortality on early-hatched fishes during inhabiting the sea.

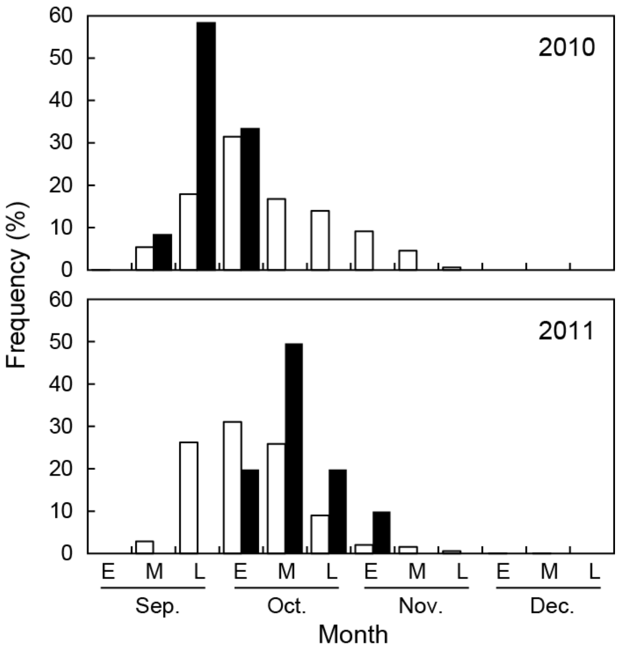


Fig. 2 Comparison of hatching date of ayu between 2010 and 2011 in the Unosumai River. Black and white bars indicate the observed and expected frequency, respectively. E, M, L indicate early, middle, late of the month.

How did the tsunami cause such selective mortality? Previous researches have shown that the ayu juveniles migrate to the river mouth before commencing migration into the river, and the juveniles hatched earlier begin this migration around March, earlier than the later hatched ones. When the tsunami occurred, the river mouths along the Tohoku region were severely eroded. Actually, a sand bar located around the mouth of the Unosumai River disappeared after the tsunami. Assuming the migration pattern of ayu, it was suggested that juveniles inhabited around river mouth were mainly composed of early-hatched fishes and were decreased by the disturbance of the tsunami.

Second, the 2011 migrants were migrated into the river at younger age and smaller size than the 2010 migrants (Fig. 3), although the growth rate and date of upstream migration were not significantly different. These results suggested that the shortened growth period in the sea caused the decrease in size and age at migration. It can be supposed that smaller sized ayu mature at later spawning period and spawn fewer eggs than larger ones. Therefore, these ecological changes would possibly lead to the decline in ayu population.

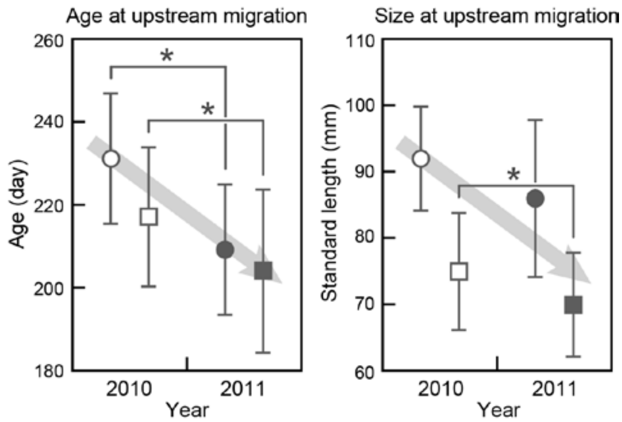
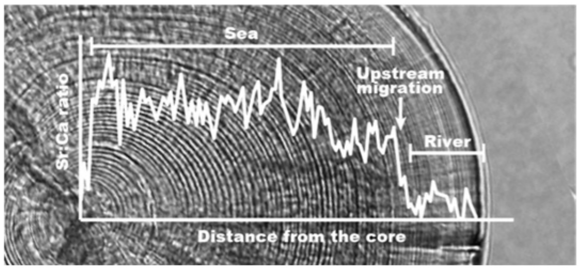


Fig. 3 Decreases in age and size of ayu juveniles at upstream migration. Data were expressed as mean ± S.D. Circles and squares indicate the Unosumai River and the Sakari River, and open and hatched symbols indicate 2010 and 2011, respectively. Asterisks (*) indicate significant differences ($p < 0.05$).

【Conclusion】

1. The tsunami probably caused a selective mortality on early-hatched ayu juveniles during their oceanic period.
2. The ayu those survived the tsunami, migrated into the river at younger age and smaller size than the ayu before the tsunami.
3. Those changes in migration history would possibly trigger the subsequent decline of ayu population.

What can otolith analysis tell us?
Otolith is tiny calcite ($CaCO_3$) crystal formed in fish's inner ear. Because otolith grows bigger by continuous accretion of calcite with somatic growth, otolith is powerful tool to investigate the life history of fishes. The age of an individual fish can be determined by counting rings those periodically formed in the otolith. The growth history can also be estimated based on relationship between otolith and body size. Furthermore, analyzing various elements in otolith those concurrently participate with calcite can indicate the past environment that the fish experienced. Sr is frequently used in research of fish migration. The seawater contains much higher concentration of Sr than the freshwater does, so the changes in otolith Sr:Ca ratio indicate the migration between the river and the sea.



【How we investigated】

To clarify the ecological changes of ayu population after the tsunami, we performed otolith microstructure and microchemistry analysis (Box). In July 2011, about 3 months after the tsunami, we collected ayu in the Unosumai River and the Sakari River, located at Kamaishi city and Ofunato city, respectively. The collected fishes were measured for standard length (SL mm) and their otoliths were extracted. The otoliths were embedded in epoxy resin, and ground and polished to the core. Their daily age was determined by counting the otolith daily rings and hatching date was back-calculated. To estimate the timing of first freshwater entry, otolith Sr:Ca ratio was analyzed using electron probe micro analyzer (EPMA). Regarding the analytical point indicating the abrupt decrease in Sr:Ca ratio was formed at the entrance to the river, daily age, body size, and date at upstream migration was estimated. Those results were compared with the results obtained in 2010 by the same method.

In addition, to estimate the initial hatching date composition, amount of drifting larvae was investigated in both rivers. The drifting larvae were collected at night using conical net dipped in the water during September to December in 2009 and 2010. The larvae were counted and its total number was estimated. Obtained seasonal changes in the number of drifting larvae could be regarded as expected hatching date composition with no selective mortality.

What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Impact of the huge tsunami on 11 March 2011 to seagrass and seaweed beds in Sanriku Coast, Japan

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Key words: impact of tsunami, seagrass and seaweed beds, Otsuchi Bay, Shizugawa Bay, fisheries

【Background】

Coastal fishing and aquacultures have been very active along Sanriku Coast facing Pacific Ocean consisting of enclosed and rias-type bays with deep bottoms. Seagrass and seaweed beds are broadly distributed there playing ecologically important roles. They are essential for the sustainable development of coastal fisheries and the maintenance of sound coastal ecosystems. However, the huge tsunami produced by the Great East Japan Earthquake on 11 March 2011 hit Sanriku Coast. The tsunami destroyed infrastructures of coastal fishers but also coastal ecosystems such as seagrass and seaweed beds indispensable for fisheries, which can be called a natural infrastructure for coastal fisheries.

【Aim】

To grasp damages of seagrasses and seaweeds forming underwater meadows or forests hit by the huge tsunami and their recovery.

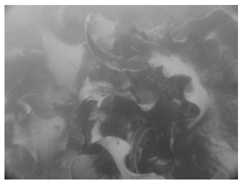
【What we found】

Fig. 1 *Sargassum horneri* (left picture) on 21 June 2011 and seedlings of *Zostera caulescens* (right picture) on 22 June 2011.

What are the differences between seagrasses and seaweeds?

Seagrasses are vascular plants evolved from terrestrial plants and have roots, leaves, and underground stems called rhizomes that hold plants in place. Most of them grow on sand beds. Seaweeds are macroalgae belonging to a taxonomic group that includes protozoans, prokaryotes, fungi, sponges, and algae. Most seaweeds require a hard substrate on which they can fix, like rocks. They lack flowers and specialized functional tissues such as roots, stems, and leaves of seagrasses and land plants. Seaweeds are divided into three groups based on their color – green, brown or red. Usually, some species of brown seaweed form underwater forests or meadows. In Sanriku Coast of Japan, representative seagrasses are *Zostera caespitosa*, *Zostera caulescens*, *Zostera japonica*, *Zostera marina*, and *Phyllospadix iwatensis* while representative seaweeds forming forests are *Saccharina japonica*, *Saccharina japonica* var. *religiosa*, *Cystoseira hakodatensis*, *Sargassum horneri* and *Eisenia bicyclis*.

Zostera calescens



Saccharina japonica

【Conclusion】

1. Seaweed beds around the coast of the mouth and the center of Otsuchi Bay were not impacted by the tsunami.
2. Seaweed beds of *Eisenia bicyclis* in the bay head of Shizugawa Bay was not heavily impacted by the Tsunami.
3. Seagrass beds in the bay head of Otsuchi Bay and Shizugawa Bay were destroyed.
4. Seedlings of seagrasses were germinated from seeds produced in the precedent years grew in Otsuchi Bay in June 2011.

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5. Seagrass beds were recovered. However, those near the river mouths of Shizugawa Bay were not recovered well due to turbid water from the rivers by construction.
6. Seaweed beds enlarged their distributions after the tsunami because of increase in hard substrates consisting of debris.
7. It is important that operations on the shallow coasts such as construction of breakwater against tsunami, restoration of ports and removes of debris (fragments of dikes) pay attentions not to destroy recovering seagrass beds.

【How we investigated】

Field survey was conducted from 19 to 23 June 2011 three months after the tsunami. Underwater camera (QI) was deployed at stations where seagrass and seaweed beds were distributed before the tsunami. Positions of the stations were localized with GPS.

To map seagrass beds and other coastal habitats in Shizugawa Bay, Miyagi Prefecture, before and after the tsunami, we used two satellite images of GeoEye-1 multi-band imagery on 4 November 2009 before the tsunami and 22 February 2012 after the tsunami. The GeoEye-1 multi-band imagery has four bands: red, green, blue and near-infrared. Near-infrared band and the other three bands were used for masking the land and classifying bottom substrates, respectively. Classes of the bottom substrates were composed of seagrass bed, seaweed bed, sandy bottom, rock reef, and turbid or deep sea. We employed a decision tree method to map seagrass beds and others bottom types in tropical waters developed by Komatsu et al. (2012).

Ground-truth was conducted on 19 and 20 October 2011, 30 and 31 May 2012, and 25 and 26 October 2012.

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What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Impact of the Great East Japan Earthquake and Tsunami on the abundance and genetic diversity of seagrass beds along the northeastern coast of Japan

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Key words: abundance, genetic diversity, ground subsidence, Sanriku Coast, seagrass, tsunami

【Background】

Approximately 50 submerged flowering plant species collectively known as “seagrass” are distributed in the world’s coastal areas. Seagrass bed communities play important roles in coastal ecosystems, including high primary productivity and providing habitat for associated fauna. The Sanriku Coast in northeastern Japan includes several small ria bays, within which seagrass beds are well-developed and five species of temperate seagrass genus *Zostera* (Zosteraceae) inhabit. The Great East Japan Earthquake, with its strong tsunami and ground subsidence, severely impacted the seagrass beds. How did the Earthquake affect the underwater plant communities?

【Aim】

To assess the impact of the tsunami on the seagrass beds along the Sanriku Coast by comparing species composition, abundance, and genetic diversity, before and after the event.

【What we found】

Species composition of each study site along the Sanriku Coast did not change between 2005 and 2012, except for the local extinction of *Zostera japonica* from Shizukawa Bay (Fig. 1). However, a large decline in abundance was found for several seagrass beds of the Coast (Fig. 2). Of these, response ratios (R) correlated to the tsunami height where the bays opened to the Pacific (Sites 1, 2, 4, 5, 9, and 12 in Fig.1) (Fig. 3). However, the correlation of R with tsunami height was not detected at the semi-enclosed inlet (Sites 10 and 11 in Fig. 1), centering around which ground subsidence was caused by the earthquake (Fig. 4). This suggests that seagrass beds declined not only because of the tsunami but also possibly because of deeper water that resulted from ground subsidence.

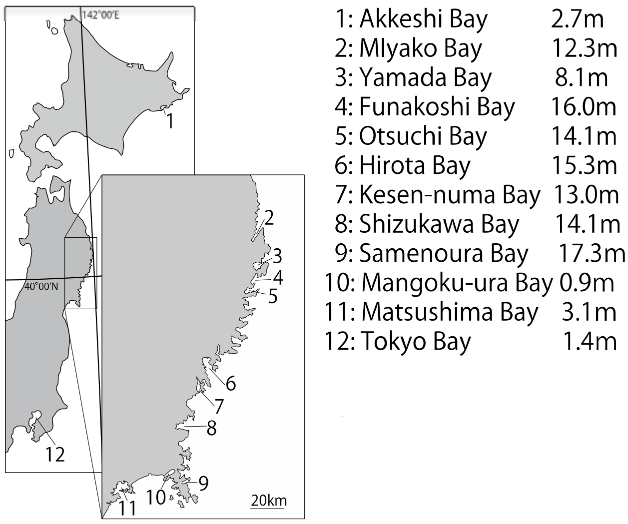

Fig. 1 Study sites and the maximum height of the tsunami.

No major change was detected in the genetic composition of eelgrass (*Z. marina*) populations after the tsunami (Fig. 5), suggesting that regenerated eelgrass individuals did not germinate from seeds dispersed from other regions but rather from the seeds preserved at the bottom of each site. Genetic diversity, from heterozygosity and other measures, generally did not change after the tsunami, except at Kesennuma Bay (Site 7) where an apparent decline in genetic and genotypic diversity was observed (Fig. 6). The decline of genetic diversity due to the decrease in the number of individuals might be a concern in the recovery of populations in the future.

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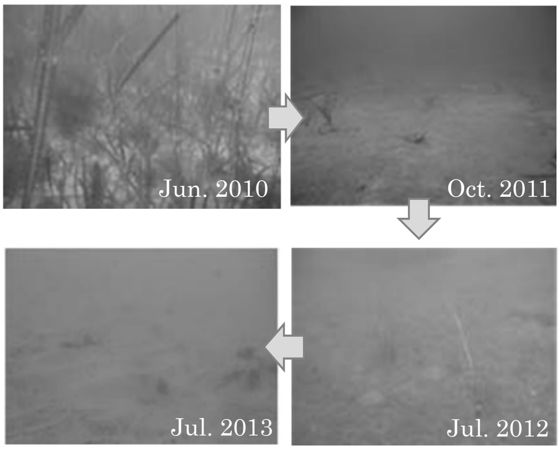


Fig. 2 Seagrass habitat before and after the tsunami at the same location in Funakoshi Bay, Iwate prefecture.

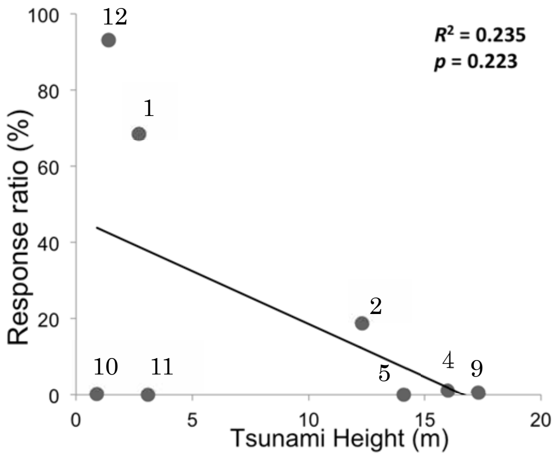


Fig. 3 Relationship between response ratio (R) and the tsunami height. R shows the change of seagrass beds abundance (density or cover) before and after the tsunami.

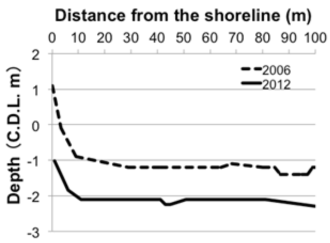
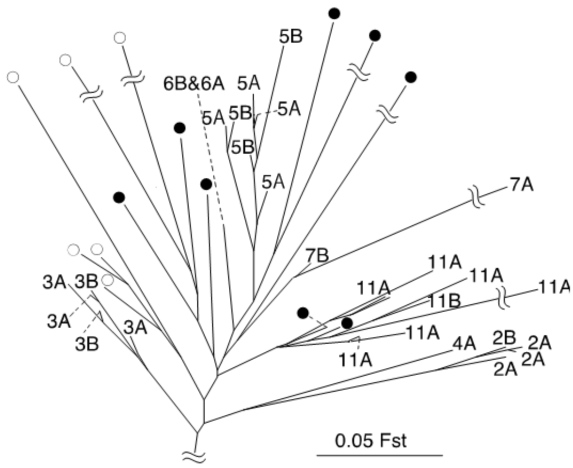


Fig. 4 Changes in bottom depth at Mangoku-ura Bay (site no. 10 in Fig. 1).



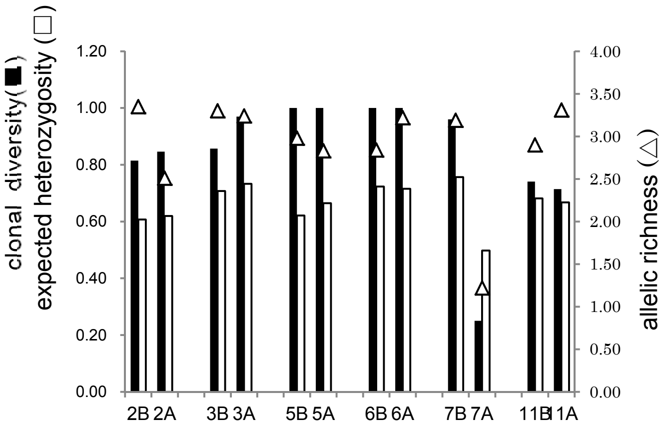


Fig. 6 Genetic diversity of eelgrass populations before and after the tsunami. Sample numbers on horizontal axis are correspond to Fig. 1 and Fig. 5.

【Conclusion】

1. A large decline in distribution and abundance of seagrass beds was found, although local extinction of seagrass species was not discerned at the time of this study.
2. Genetic composition and diversity of eelgrass populations did not change at most sites.
3. Continued biological monitoring of damaged sites is very important to evaluate recovery processes.

【How we investigated】

Study sites were mainly located along the Sanriku Coast which is close to the epicenter. Since 2011, data regarding species composition and abundance were collected by visual inspection. The rate of change was measured by the formula R (%) = (M_{after}/M_{before}) × 100, where R is the response ratio, M_{after} is the mass of seagrass after the tsunami, and M_{before} is the mass of seagrass before the tsunami. Genetic diversity was analyzed using nuclear DNA microsatellite polymorphisms for eelgrass populations collected before and after the tsunami.

←Fig. 5 Genetic relationship among eelgrass populations before and after the tsunami. The tree was constructed by Neighbor-joining (NJ) method using F_{st} values. Clusters including the Sanriku Coast populations are partly shown. Sample numbers are correspond to the site numbers in Fig.1. A and B after numbers mean samples After and Before the tsunami. Open circles mean populations before the tsunami located along the Sanriku Coast other than this study's sites and filled circles mean populations before the tsunami other than the Sanriku Coast.

Succession of benthic animals and bioturbation after the tsunami disturbance

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Key words: benthos, Onagawa, Funakoshi, Otsuchi

【Background】

The huge tsunami waves induced by the 2011 M9.0 Tohoku-Oki Earthquake severely affected shallow marine ecosystems along the Pacific coast of northeastern Japan. Among shallow marine environments, subtidal seafloor composed of fine-grained sediments (sand and mud) are the most heavily disturbed by tsunami waves, as they are radically altered by rapid erosion and deposition of the seafloor. It indicates benthic animals in subtidal seafloor ecosystems were severely affected by the 2011 tsunami disturbance. Demise of benthic animals by the tsunami also indicates decline of bioturbation in the seafloor sediments.

【Aim】

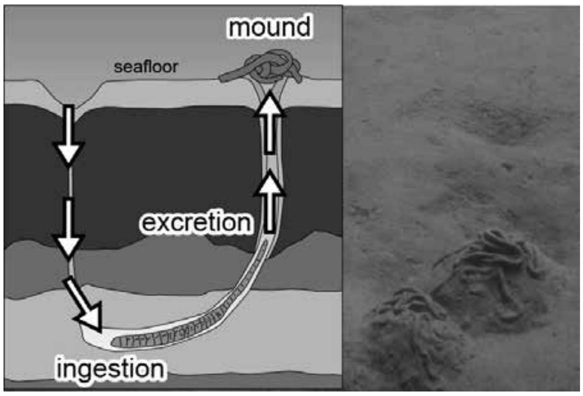
Changes and recovery in the subtidal benthic assemblages and bioturbation in soft-bottom environments following a tsunami were monitored by SCUBA equipment and sediment core samples collected during the research cruises of the R/V Tansei Maru and the R/V Shinsei Maru.

【What we found】

In Otuchi and Funakoshi bays, Iwate Prefecture, episodic changes in topography and grain-size composition occurred on the seafloor after the tsunami. Some benthic animals disappeared after the 2011 tsunami, synchronous with changes in the seafloor environment. This indicates that the 2011 tsunami severely impacted the megafaunal assemblage in the soft bottoms of the bays. In addition, it was found that the reestablishment of some benthic animal populations began within 18 months of the tsunami disturbance (Fig. 1).

In Onagawa Bay, Miyagi Prefecture, sediment core samples revealed that recolonization of the seafloor sediment by large and deep-burrowing animals began within 3 years of the 2011 tsunami. Bioturbation, intense sediment mixing by large burrowing animals has been homogenizing the sea floor sediment in this bay since 2012 (Fig. 2).

What is bioturbation?
Reworking of seafloor deposits by the benthic animals is called as bioturbation. Bioturbation is important in seafloor environments, because it influences the chemistry of seafloor sediment, affects other small organisms and microbes in the sediment. Bioturbation also contributes to the productivity of overlying waters and to global elemental budgets. Fecal mounds and burrow openings on seafloor surface are the signs of bioturbation, subsurface activities of large benthic animals.



Bioturbation by a marine worm (left) and its fecal mound on seafloor (right).

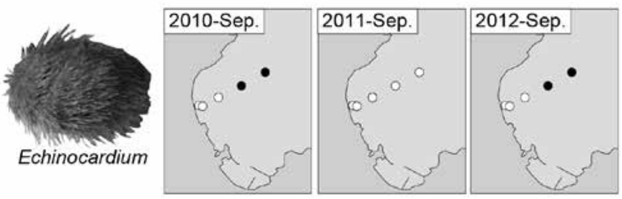


Fig. 1. Succession of the heart urchin *Echinocardium* distribution in Funakoshi Bay. Solid circle: presence, open circle: absence.

【Conclusion】

1. Field survey revealed demise of deep-burrowing animals shortly after the tsunami, and its re-establishment occurred after 3 years in Onagawa Bay and after a year and a half in Otsuchi and Funakoshi bays.

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2. However, the current benthic colonization is possibly less abundant than before the tsunami. The benthic assemblages are still in the recovery process from the impact of the tsunami.
3. Continued monitoring in the future is vital to understanding the nature of the succession of the benthic assemblages and bioturbation in the area, and for assessing the long-term effect of tsunami waves on the seafloor ecosystem.

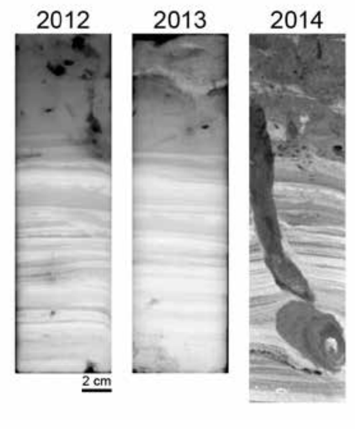

Fig.2. CT image for the core samples of Onagawa Bay.

【How we investigated】

Underwater field surveys with SCUBA equipment were carried out on Otsuchi and Funakoshi bays, northeastern Japan before the tsunami (September 2010) and after the tsunami (September 2011 and September 2012), providing a rare opportunity to evaluate the impact of the tsunami on shallow marine seafloor topography, sediments, and megabenthos assemblages.

Sediment cores were sampled during research cruises by the R/V Tansei Maru and the R/V Shinsei Maru using multiple corer, in October 2012, December 2013, and April 2014. Sediment core samples were examined using X-ray radiography, computed tomography scanning, and grain size analysis to identify temporal changes in the physical sedimentary structures and bioturbation of seafloor deposits in Onagawa Bay, northeastern Japan, following the 2011 tsunami.

【Further readings and information】

Abe, H., Kobayashi, G., Sato-Okoshi, W. (2015) Impacts of the 2011 tsunami on the subtidal polychaete assemblage and the following recolonization in Onagawa Bay, northeastern Japan. *Marine Environmental Research*, 112(Part A), 86–95. doi:10.1016/j.marenvres.2015.09.011

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Soft bottom benthos in nearshore areas of Iwate Prefecture, Japan

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Key words: soft bottom, benthos, abundance, diversity

【Background】

The Great East Japan Earthquake on March 11, 2011 caused considerable damage to the Pacific coastal areas of the Tohoku region of Japan. Particularly, the tsunami of the earthquake disturbed benthic habitats and a large amount of debris was deposited on seafloors. These disturbances could provide great impacts on local benthic communities, change the composition and amount of infauna and potentially affect the distribution of commercially valuable marine organisms and fisheries activities. Thus, it is necessary to monitor spacio-temporal distribution of benthic communities in the disaster area to assess residual effects of the tsunami and to understand recovery processes of coastal ecosystems.

【Aim】

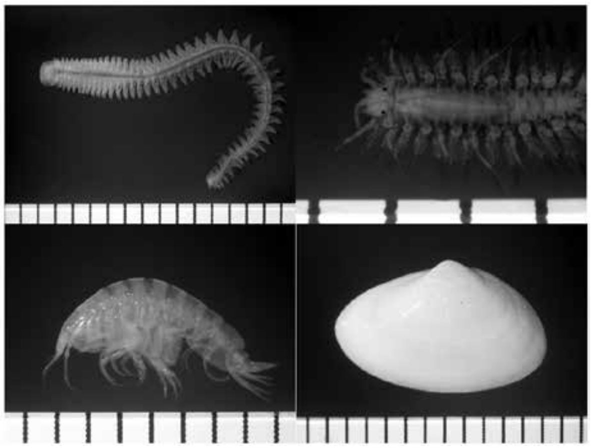
This study aims to examine the condition of benthic community in shallow water soft bottom after the Great East Japan Earthquake in Hirota Bay, Ofunato Bay, Toni Bay, Okirai Bay in Iwate Prefecture, Japan. Additionally, the abundance and diversity of soft bottom benthos were compared among bays to better understand local characteristics of coastal ecosystem in the study area.

【What we found】

The density of macrobenthic animals in each sampling station ranged from 540 from 8,285 ind./m^2 in the study area. The mean density (ind./m^2) was higher in Ofunato Bay (mean ± s. d. = 3,932 ± 2,559) than others (1,815 ± 1,247 in Hirota Bay, 1,561 ± 1,235 in Okirai Bay and 1,541 ± 692 in Toni Bay) but there was no significant difference among bays (Kruskal-Wallis test, $p = 0.102$). In Hirota Bay, Okirai Bay and Toni Bay, Annelida (polychaetes) and Arthropoda (mostly crustaceans) were abundant in density, and Mollusca was subsequently dominant (Fig. 1A). However, in Ofunato Bay, Arthropoda and

Soft bottom habitats and the inhabitants

Soft bottoms or soft sediment bottoms are seabeds consists of fine grain sediments, mud and sand. They cover over 80 % of the ocean seafloor. Thus, it is one of the largest habitat types on earth. In soft bottom habitats, organisms can burrow into sediment as well as live on sediment surface. Therefore, soft bottoms are 3-dimensional habitats, and a lot of burrowing animals such as bivalves are observed. Benthic biomass of soft bottom habitats is generally dominated by macroinvertebrates, including polychaete worms, crustaceans, molluscs and echinoderms. Those soft-sediment organisms often provide important ecological goods and services. Many commercially valuable crabs, shrimps and bivalves live on or in soft bottoms, and those animals recycle nutrients, detoxify pollutants and represent important trophic links in marine ecosystems.



Examples of soft bottom benthos. Polychaetous annelids (upper left and right), amphipod crustacea (lower left) and bivalve (lower right).

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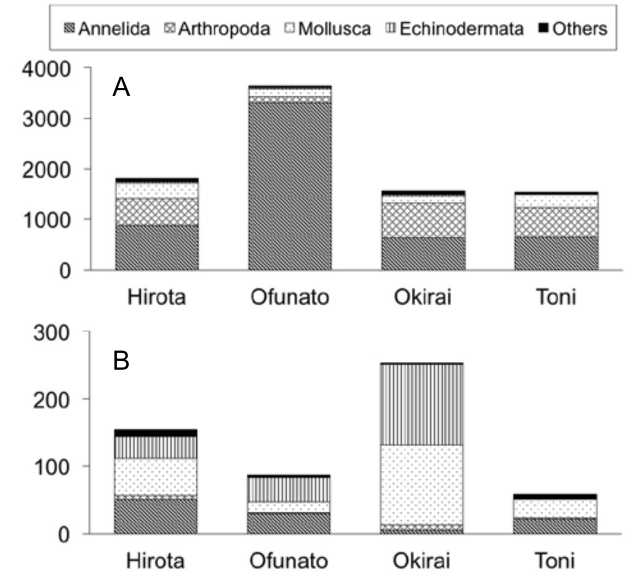

Fig. 1. Mean density and biomass of major taxonomic group in each bay. A: density (ind./m^2), B: wet weight biomass (g/m^2)

Mollusca were scarce, and 91 % of individuals were polychaetous annelids.

The wet weight biomass of macrobenthos (g/m^2) ranged from 11.9 to 633.3. The mean (± s. d.) was 154.6 ± 183.0 in Hirota Bay, 62.4 ± 45.7 in Ofunato Bay, 253.4 ± 126.5 in Okirai Bay and 58.4 ± 56.6 in Toni Bay (Fig. 1B), and significant difference was observed between Ofunato Bay and Okirai Bay (Steel-Dwass test, $p < 0.05$).

Total 297 species were found in this study, and over 80 species were found in each bay. The diversity index ranged from 3.27 to 5.09 in Hirota Bay, from 0.77 to 3.51 in Ofunato Bay, from 3.55 to 5.12 in Okirai Bay and from 4.15 to 4.87 in Toni Bay, and the index was significantly lower in Ofunato Bay than in other bays (Steel-Dwass test, $p < 0.05$) (Table 1).

Table 1. Differences in mean (± standard deviation) diversity index among bays.

Hirota Bay	Ofunato Bay	Okirai Bay	Toni Bay
4.36 ± 0.59[a]	2.21 ± 0.95[b]	4.44 ± 0.65[a]	4.53 ± 0.28[a]

Diversity indices with the same superscript are not significantly different ($p > 0.05$) from one another (Kruskal-Wallis test, posteriori Steel-Dwass test).

【Conclusion】

1. A wide variety of benthic organisms were found in the study area, and the density and biomass were high in several sampling stations.
2. Polychates are quite dominant in Ofunato Bay. They occurred in very high density but the mean of total biomass was small, meaning a large number of small polychaete species were involved in samples collected from Ofunato Bay.
3. Diversity indices of Hirota Bay, Okirai Bay and Toni Bay were at same level but those of Ofunato Bay were significant lower. This may indicate the specific environmental condition in Ofunato Bay, such as the eutorophicated bottom sediment.

【How we investigated】

We set 10 sampling stations in Hirota Bay as well as Ofunato Bay and five stations in Okirai and Toni Bay, respectively, as they distributed from the innermost part to entrance of each bay. Every two mud samples were collected at a station by using a Smith-Mcintyre grab with a sampling area of 0.1 m^2 during June-July 2013. Macrobenthos were sorted out after sieving mud samples with 1 mm mesh. In the laboratory, macrobenthos were identified, counted and weighted. The data of two replicates in each station was combined in this study.

The density (ind./m^2) and wet weight biomass (g/m^2) of macrobenthos were compared among bays with Kruskal-Wallis test and posteriori Steel-Dwass test. Additionally, Shannon-Wiener indices were calculated to assess the difference in macrobenthic diversity among bays. All statistics were conducted by using the R software and the Vegan package.

【Further readings and information】

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What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Changes in sediment geochemistry and the distribution of benthic organisms at bathyal depths after the 2011 off the Pacific coast of Tohoku Earthquake

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Key words: event deposit, nutrient, sedimentary organic matter, prokaryote, meiofauna

【Background】

The 2011 off the Pacific coast of Tohoku Earthquake (hereafter, the 2011 Tohoku earthquake) and the subsequent tsunami caused mass sedimentation events on the vast seafloor of off Tohoku. Event deposits of up to tens of centimeters thickness have been found in vast areas, with large spatial variations in their thicknesses. Those event deposits are expected to be affected benthic environments and organisms.

【Aim】

We investigated the effects of mass sedimentation events caused by the 2011 Tohoku earthquake on benthic geochemistry and ecosystems using sediment cores collected in 2012 and 2013 from eight bathyal stations (310 to 880 m water depths) off Tohoku, northeast Japan.

【What we found】

One to seven cm thickness of event deposits were observed at all of the sampling stations in 2012. In 2013, some of these event deposits were disturbed or covered by newly deposited sediment layers. Carbon and nitrogen isotopic compositions, together with the C/N ratio, suggested that the event deposits were composed of local sediments that had been transported relatively short distances. Nutrient fluxes across sediment-water interface correlated with total organic carbon in surface sediments and dissolved oxygen concentrations in the bottom water. Nutrient fluxes did not show any correlation with event deposit thickness, probably due to the deposition of local sediments containing similar quality and quantity of organic matter. In 2013, nutrient fluxes increased at deeper sites (840 to 880 m water depths), suggesting increased organic matter mineralization at the sites, although the difference in sampling season might influence the nutrient fluxes.

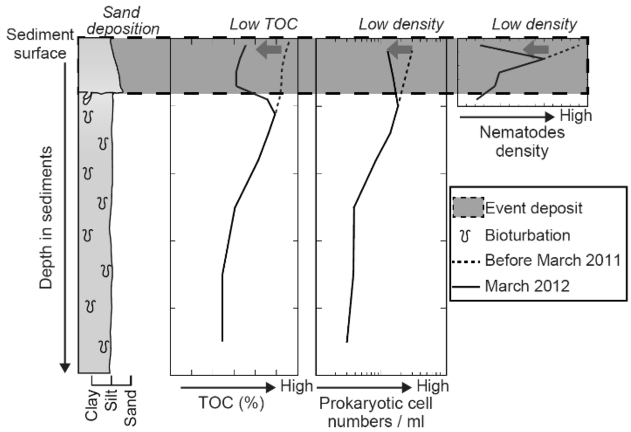

Fig. 1. Schematic figure of sediment lithology, changes in total organic carbon concentration, prokaryotic cell numbers, and nematodes numbers of the sediments before the earthquake (dotted line, presumable profiles) and March 2012. The depth corresponds to the event deposit is indicated as dotted box.

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At some stations in 2012, prokaryotic cell abundances were lower in the surface event-deposit layers compared to those in deeper sediments (Fig. 1). The variations were explained by environmental parameters such as mean grain size and sorting factor, suggesting that turbidite sedimentation affected prokaryotic cell abundances. Nematodes abundance, which commonly presents surface peaks at the deep-sea floor, presented subsurface peaks at the stations where subsurface peak of prokaryotic cell numbers were observed. In contrast, maximum abundance of copepods was always found in the surface layer. The subsurface peaks of prokaryotic cell numbers and nematodes densities were still observed in November 2013, indicating that effects of episodic sedimentation events on scales of several centimeters still remains on small organisms inhabiting sediments.

Meiofauna

Benthic organisms are conventionally classified into several size classes: megafauna, macrofauna, meiofauna, and microfauna, in order of size from larger to smaller. Meiofauna are organisms passing through a 500-μm (or 1000-μm) mesh but remaining on a 44-μm (or 63-μm) mesh (Giere 2009). They are abundant in the seafloor, in particular at the deep-sea floor, and play important roles in biogeochemical cycles in sediments. Major meiofauna in the deep-sea are nematodes (lower right figure), benthic foraminifera, and harpacticoid copepods (lower left figure).

Scale bars = 500 μm

【Conclusion】

The 2011 Tohoku earthquake and tsunami provoked several cm thickness of sedimentation events on the bathyal depths off Tohoku. The sedimentation did not have obvious effects on benthic nutrient fluxes one year after the earthquake. The vertical distributions of prokaryote and nematodes, however, were affected by those sedimentation events and showed subsurface peaks in their densities. Ongoing time-series sampling will provide novel insights into the resilience of deep-sea organisms to the disturbance event.

【How we investigated】

Surface sediment samples were collected from eight bathyal sites off Tohoku using a Barnett-type multiple-corer during the MR12-E02 leg 3 cruise of R/V *Mirai* in March 2012 and the BO13-20 cruise of R/V *Boseimaru* in November 2013. Obtained sediment samples were examined for sedimentological analyses, total organic matter contents and their isotopic compositions, porewater nutrient concentrations, prokaryote cell counts, and meiofaunal distributions in sediments.

【Further readings and information】

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MR12-E02 Leg 3 Cruise Report is available at the following URL: http://www.godac.jamstec.go.jp/catalog/data/doc_catalog/media/MR12-E02_leg3_all.pdf

What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Zooplankton community in Otsuchi Bay, northeastern Japan after the 2011 Tohoku earthquake tsunami

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Key words: tsunami, Tohoku, Otsuchi Bay, zooplankton, copepods

【Background】

A huge tsunami generated by the 2011 off the Pacific coast of Tohoku Earthquake struck the eastern coast of Japan and induced significant alterations in coastal habitats. In Otsuchi Bay on the Sanriku Coast, the tsunami destroyed the sand bar that had formed at the mouth of the Unosumai River and other coastal structures such as breakwaters. Aquaculture facilities in the bay were totally collapsed by the tsunami. These environmental changes potentially influence plankton communities of the bay at the local scale through changes in hydrodynamics and nutrient supply. Furthermore, the absence or significant reduction of cultured shellfish and seaweed could also affect plankton communities in the bay, as they are potential competitors or consumers of planktonic organisms. Based on these backgrounds, we have surveyed plankton communities in Otsuchi Bay since May 2011, two months after the tsunami. Here we report seasonal changes in abundance and distribution of mesozooplankton (planktonic animals in the size range of 0.2–20 mm) in the bay during the two years from May 2011 to May 2013.

【Aim】

The aim of the present study was to elucidate the effects of the tsunami on mesozooplankton community in Otsuchi Bay.

【What we found】

Mesozooplankton abundance and composition showed a similar seasonal variation in each of the two years after the tsunami (Fig. 1). Comparison with pre-tsunami data for communities from the bay showed that seasonality in dominant holoplanktonic taxa, such as copepods, appendicularians and cladocerans did not change before and after the tsunami.

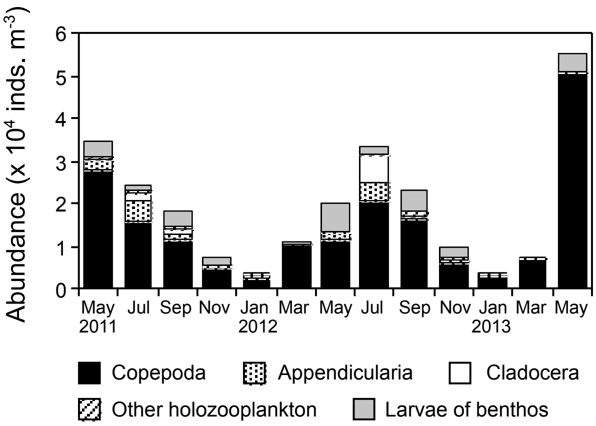

Fig. 1. Seasonal changes in abundance and taxonomic composition of mesozooplankton at the central station (Stn. 2) in Otsuchi Bay from May 2011 to May 2013.

In our first sampling after the tsunami (May 2011), the copepod communities in the central bay consisted mainly of *Acartia hudsonica*, *A. longiremis*, *Clausocalanus pergens*, *Paracaranus parvus* s.l., *Pseudocalanus newmani*, *Oithona similis* and *O. atlantica*. The dominance of these copepod species was also reported in the same central area during spring (April–May) before the tsunami. For the rest of the first year, the abundant copepods in the central bay were comparable to those in the corresponding months or seasons during the pre-tsunami period. These suggest that the tsunami did not have a significant impact on the copepod community structure in the bay, or if any, the community had rapidly recovered from the disturbance by our first sampling after the tsunami.

The copepods producing resting eggs and planktonic larvae of benthic invertebrates are expected to have affected by the tsunami disturbance also on the bottom sediments. The copepod *A. hudsonica* has been shown to produce resting eggs. This copepod was observed with high abundance in the inner part of the bay immediately after the tsunami (May 2011) as well as one and two years

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later (May 2012 and May 2013, respectively) (Fig. 2). This result suggests that *A. hudsonica* population in the bay had recovered within two months after the tsunami.

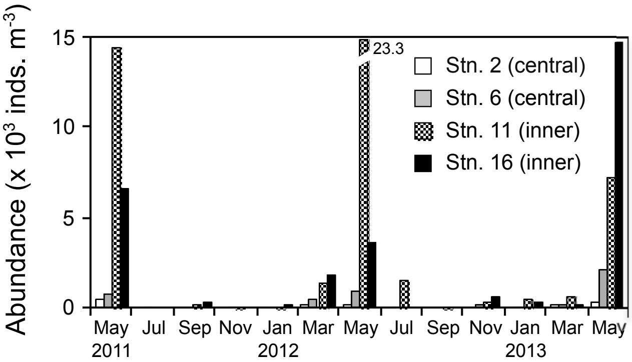

Fig. 2. Seasonal changes in the abundance of adult *Acartia hudsonica* at four stations in Otsuchi Bay from May 2011 to May 2013.

During the two years of study after the tsunami, dominant taxa of larval benthic invertebrates (bivalves, gastropods and polychaetes) showed higher densities in the warmer months between May and November. However, at the most inner part of the bay where the sea-floor environment was disturbed considerably by the tsunami waves, larval abundance in May 2011 was much lower than that in the following period from July to September (or November) in 2011 or in May 2012 and May 2013 (Fig. 3). Hence, the reduced abundance of planktonic larvae might have resulted from damage to the benthic adult populations.

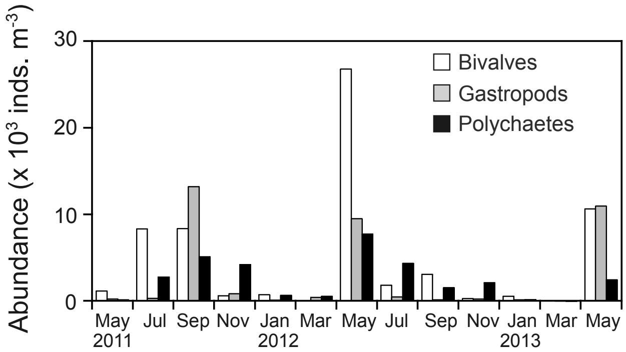

Fig. 3. Seasonal changes in abundance of dominant planktonic larvae of benthic invertebrates (bivalves, gastropods and polychaetes) at the most inner station (Stn. 16) in Otsuchi Bay from May 2011 to May 2013.

【Conclusion】

Our findings suggest that the tsunami did not have a significant or lasting impact on the mesozooplankton communities in Otsuchi Bay, particularly for holoplanktonic taxa. This absence of apparent effects on the communities may be explained, in part, by the hydrologic characteristics of the bay, as an intense water exchange occurs frequently between the bay and the adjacent offshore waters. In contrast, the reduced abundance of planktonic larvae of benthic invertebrates was found in the inner part of the bay just after the tsunami, possibly due to the damage to the benthic adult populations.

Copepods -a tiny but abundant crustacean

Copepods are aquatic animals, being probably the most numerous multicellular organisms on Earth. At present more than 11,500 species are known. Copepods inhabit all aquatic environments, and have various ways of life including planktonic, benthic and parasitic modes. In marine pelagic environments, copepods are mostly 0.5–2 mm total length as adults and are the most numerous group in metazoan zooplankton. They feed mainly on phytoplankton and in turn are preyed on by fishes. Therefore, copepods play an important trophic role in marine ecosystem.

【How we investigated】

Seasonal sampling was conducted bimonthly from 27 May 2011 to 28 May 2013 at four stations located from the central (Stns. 2 and 6) to the inner areas (Stns. 11 and 16) of Otsuchi Bay. Zooplankton samples were collected with a plankton net with 0.1 mm mesh by vertical hauls from near the bottom to the surface. The samples were fixed, and then mesozooplankton was identified and enumerated under a dissecting microscope. The results obtained were compared with data collected before the tsunami in order to examine the differences between pre- and post-tsunami communities.

【Further readings and information】

Nishibe, Y., Isami, H., Fukuda, H., Nishida, S., Nagata, T., Tachibana, A. and A. Tsuda (2016) Impact of the 2011 Tohoku earthquake tsunami on zooplankton community in Otsuchi Bay, northeastern Japan. *Journal of Oceanography*. DOI: 10.1007/s10872-015-0339-8

Seasonal change of phytoplankton community in Otsuchi Bay, northeastern Japan after the 2011 off the Pacific coast of Tohoku Earthquake and tsunami

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Key words: Phytoplankton, Diatom, Otsuchi Bay, Earthquake, Seasonality

【Background】

The coastal environments of the Sanriku region in Japan was disturbed by a huge tsunami caused by the 2011 off the Pacific coast of Tohoku earthquake. The collapse of coastal structures and backwash from land altered nutrients condition in the coastal region. These tsunami-induced environmental changes could also affect coastal pelagic ecosystems. Phytoplankton are the primary producers and are fed to zooplankton and shellfish on aquaculture facilities. Understanding of phytoplankton status is important to the recovery of ecosystem and fishery reconstruction. We are indicated monitoring study to elucidate plankton community dynamics in Otsuchi Bay during a two-year period (May 2011 to May 2013). Seasonal changes in phytoplankton abundance and species composition were recorded from four locations of the Otsuchi Bay since May 2011, two months after the tsunami.

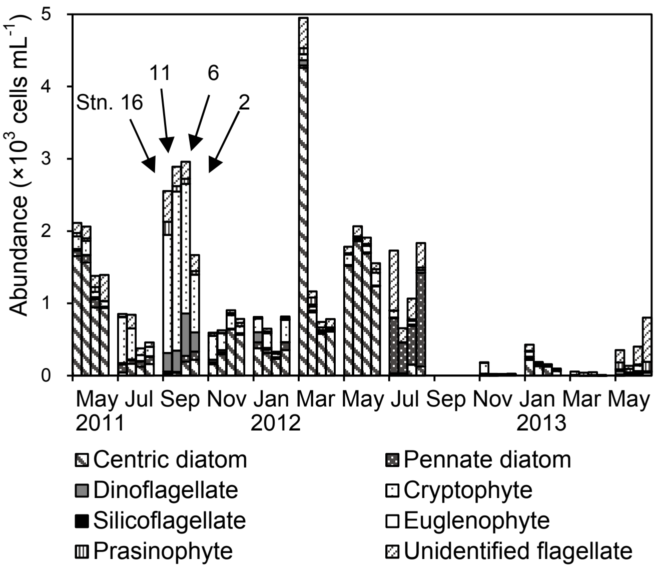

Fig. 1. Seasonal change and taxonomic composition of phytoplankton at four stations in Otsuchi Bay from May 2011 to May 2013.

【Aim】

To assess the seasonal changes in phytoplankton abundance and species composition, and discuss changes in the phytoplankton community in Otsuchi Bay after the tsunami.

【What we found】

Phytoplankton abundance were observed a similar seasonal fluctuation at four sampling stations, although relative high abundance appeared at the inner part of the bay (Fig. 1). The centric diatoms increased during winter to spring, while cryptophytes and pennate diatoms dominated during summer to fall. Dinoflagellates mainly appeared in the inner part of the bay between September and January.

The cluster analysis revealed the appearance of mainly two seasonally distinct communities in the Otsuchi Bay (Fig. 2). The samples collected from same month showed high similarity irrespective of sampling stations, which indicated a uniform distribution of surface phytoplankton community in the bay. The timing of shift between communities occurred in the same period during the two years. The spring-summer community appeared from May to September and was characterized by an increase of warm-water *Chaetoceros* species (*Chaetoceros diadema* and *C. lorenzianus*) and by the appearance of a lot of dinoflagellates species. The fall-winter community appeared from November to March and was characterized by the cold neritic species such as *Chaetoceros socialis* and *Thalassiosira nordenskioekdii*. The dominant phytoplankton species in both communities were similar to a previous study which observed in the same season before the tsunami. Furthermore, phytoplankton species composition in our first sampling after the tsunami (May 2011) agreed well with those observed in May 2012 and May 2013, which categorized in spring-summer community.

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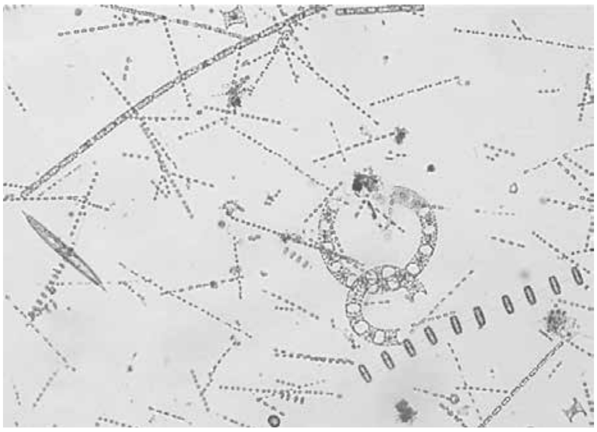
Phytoplankton ecology

Phytoplankton are microscopic organisms that inhabit euphotic zone of ocean, lake and other water environments. Like a terrestrial plant, they have chlorophyll and generate organic compounds and O_2 via by photosynthesis. Therefore, phytoplankton play a key role in marine ecosystems as primary producers. Carbon fixation by phytoplankton in the open ocean is almost equal to that of terrestrial plant. Phytoplankton growth also requires nutrients such as nitrate, phosphate and silicate. "Red tides" or "Harmful algal blooms" often occur in coastal region due to eutrophication. These phenomenon are also potentially harmful to human health.



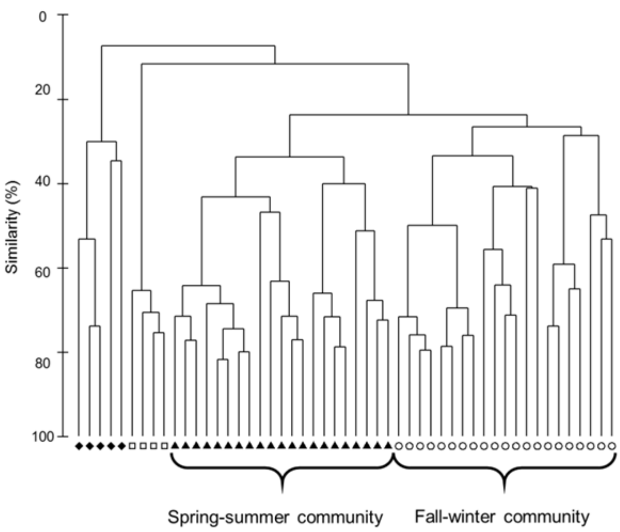


Fig. 2. Cluster dendrogram of the phytoplankton community in the bay from May 2011 to May 2013.

【Conclusion】

Our findings suggest that there was no serious impact of the huge tsunami on the phytoplankton community in Otsuchi Bay. The change in nutrients condition by the tsunami did not have a significant effect on the seasonal variation of the phytoplankton community structure.

【How we investigated】

Seasonal samplings were carried out in Otsuchi Bay at four stations located from the central (Stns. 2, 6) to the inner area (Stns. 11 and 16), once every two months from May 27, 2011 to May 28, 2013. The seawater samples for phytoplankton were collected at a depth of 1 m using a Niskin water sampler. The seawater (1 L) was fixed with acid Lugol's solution (final concentration, 5% v/v). The phytoplankton cells were concentrated to approximately 50 mL by precipitation, and phytoplankton were identified and counted using an inverted microscope at a magnification of ×40–400 (1–1/40 area of chambers) with standard settling chambers. To examine the phytoplankton community structure, we conducted the cluster analysis using the Bray-Curtis similarity index.

【Further readings and information】

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Seasonal migration of sea turtles to a temperate habitat in Sanriku Coastal Area

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Key words: by-catch, mark-recapture, Satellite tracking, Juvenile turtles

【Background】

Both loggerhead and green turtles are listed on the IUCN Red List of Threatened Species (loggerhead: vulnerable; green: endangered). While information on entire life cycle is essential for designing effective conservation management, most studies of sea turtles are concentrated around nesting beaches ranging from tropical to southern temperate regions. Our study site in the Sanriku Coast is situated in northern temperate area more than 500 and 1500 km north of the major Japanese nesting sites for loggerhead and green turtles, respectively. Anecdotal information from local fishermen has suggested that turtles occasionally migrate to this area. Thus, it is possible that this area hosts important foraging habitats for populations in North Pacific.

【Aim】

Aims of this study are to reveal in what season and at which life stage turtles are found along the Sanriku Coast, and to examine where they were born and where they go after leaving the Sanriku Coast. In addition, we compared migration routes and body condition of turtles before and after the tsunami in 2011.

【What we found】

From 2005 to 2015 (excluding 2011 because of the tsunami), a total of 262 loggerhead turtles *Caretta caretta*, 93 green turtles *Chelonia mydas* (including 3 black turtles *Chelonia mydas agassizii*) and a few leatherback turtles *Dermochelys coriacea* were incidentally captured in set-nets. By-catch mortality rates of the loggerhead and green turtles were not high (5 and 5%, respectively) because the set nets adopted in the study site consist of large nets stretched vertically from the sea surface to the bottom without covering the top of the nets. By-catch incidents after 2011 indicated that turtles continued to migrate to the Sanriku Coast after the tsunami. Both species visited between mid-June to late-November (Fig. 1).

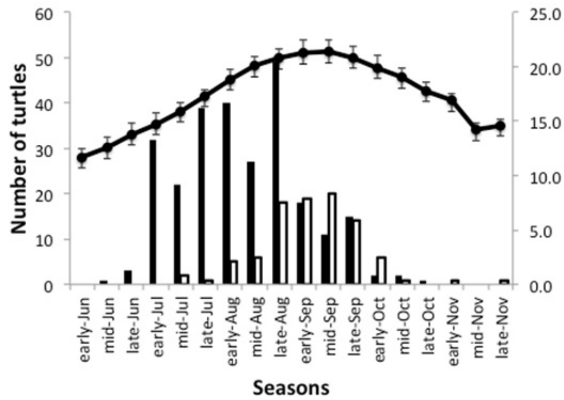

Fig. 1. Number of loggerhead (black bars) and green turtles (white bars) captured at the study site, and mean(±SD) sea surface water temperatures (SST) measured at fixed observation points in Kamaishi and Yamada bays.

Straight carapace length (SCL) of turtles ranged from 49.5 to 92.0 cm (loggerhead: mean ± s.d. = 72.2 ± 6.5 cm, n = 262) and from 36.8 to 90.9 cm (green: mean ± s.d. = 49.1 ± 12.0 cm, n = 93). An obvious extension of tail, which is a secondary sexual characteristic of males, was recognized in some loggerhead (n=45) and green (n=1) turtles. Body mass (BM) ranged from 21.5 to 109 kg (loggerhead: mean ± s.d. = 58.7 ± 14.0 kg, n = 255) and from 7 to 104 kg (green: mean ± s.d. = 20.6 ± 18.9 kg, n = 91). SCL and BM were significantly correlated in both species (green $BM=0.0002 \times SCL^{2.93}$; loggerhead $BM=0.0011 \times SCL^{2.53}$) and there was no significant difference in body condition index ($BM/SCL^{2.53}$ for loggerhead and $BM/SCL^{2.93}$ for green) before and after the tsunami.

Population genetic analyses revealed that turtles migrated to Sanriku mainly originated from southern rookeries in Japan (Yakushima for loggerhead and Ogasawara for green). Based on mark-recapture study and satellite tracking data, both species

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predominantly utilize the Sanriku coastal area and surrounding oceanic waters during summer. Then, loggerhead turtles spent most of their winter time traveling in oceanic waters (>200 m) several kilometers east of Japan and green turtles moved along with coastline more than 500 km from Sanriku Coast to southern overwintering sites as progress of season (Fig. 2).

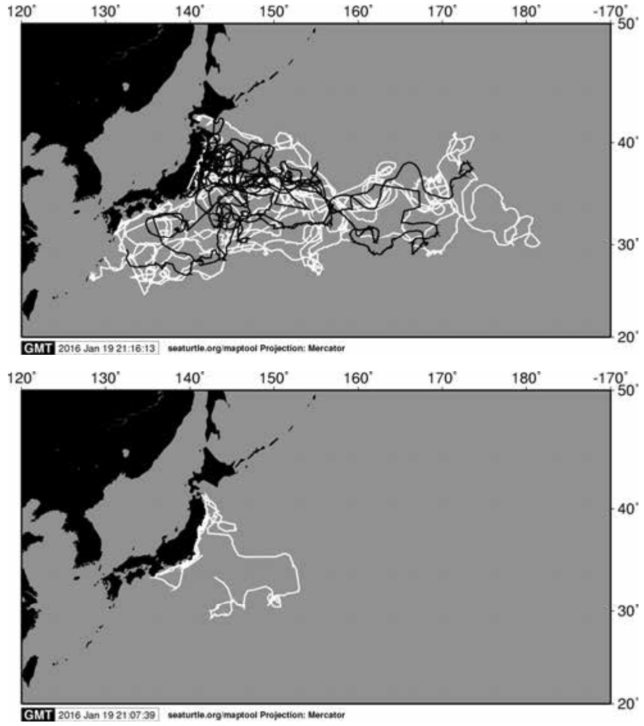

Fig. 2. Satellite tracks of (upper panel) loggerhead (black line: n=9 before 2011; white line: n=16 after 2011) and (lower panel) green turtles (white line: n=12 after 2011).

【Conclusion】

The first quantitative survey in northern Japan revealed that the Sanriku Coast served an important summer-autumn foraging habitat for large juvenile loggerhead and small juvenile green turtles in the western North Pacific. Fortunately significant differences in migrating season, body size, body condition and post-migration route were not detected before and after the tsunami.

【How we investigated】

Since 2005 we have conducted by-catch survey at the Sanriku Coast (38°55′–39°40′N, 141°40′–142°05′E), Japan. We collected turtles from commercial set nets between Miyako and Ofunato (Iwate Prefecture, Japan) and transferred to the outdoor tanks of the International Coastal Research Center, Atmosphere and Ocean Research Institute, the University of Tokyo (39°21’05N, 141°56’04E), where they were retained for 1 day to up to 3 month. We measured straight carapace length and body mass. All turtles were released from the study area after applying plastic and metal ID tags issued by the Sea Turtle Association of Japan (Non-Profit Organization: http://www.umigame.org/). Some of the captured turtles were used for Bio-logging studies (Narazaki et al. 2013) and DNA analysis (Nishizawa et al. 2014a,b). To examine their year-round distribution and diving behavior, we deployed satellite relay data loggers (SRDL) on the carapace of both species and released from Otsuchi Bay (39°20’30N, 141°56’00E). The locations of SRDLs were determined using ARGOS system. To reconstruct the migration route of each turtle, we used locations of accuracy class 3, 2, 1 and 0. In addition, implausible locations having unnaturally high swim speeds (>9 km h^{-1}) were filtered out from the track.

【Further readings and information】

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Narazaki, T., Sato, K., Abernathy, K. J., Marshall G. J. and Miyazaki, N. (2013) Loggerhead turtles (*Caretta caretta*) use vision to forage on gelatinous prey in mid-water. *PLoS ONE* 8: e66043.

Narazaki, T., Sato, K. and Miyazaki, N. (2015) Summer migration to temperate foraging habitats and active winter diving of juvenile loggerhead turtles *Caretta caretta* in the western North Pacific. Marine Biology 162: 1251–1263.

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Nishizawa, H., Narazaki, T., Fukuoka, T., Sato, K., Kinoshita, M. and Arai, N. (2014b) Juvenile green turtles in the northern edge: mtDNA evidence of long-distance westward dispersals in the Northern Pacific Ocean. *Endangered Species Research* 24: 171–179.

Identification of active bacterial community in the temperate coastal region of Sanriku area

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Key words: microbial community, gene expression

【Background】

Prokaryotic microorganisms are present in almost any terrestrial and aquatic environments on the earth. They are assumed to contain enormous numbers of species, most of which are not cultured yet and still unknown. Currently, their presence is confirmed only from a presence of genes, that are essential components of any living organisms on the planet. As the biomass of prokaryotes is estimated to account for approximately 50% of the living organisms in the ocean, they may play significant roles on the global elemental cycles. The understanding of their ecological roles leads to clarify how marine ecosystems are responding to various environmental disturbances and maintained.

Recently, microbial ecologists routinely use molecular approach analyzing environmental DNA to identify what kinds of genes are present in the environments. However, not all the genes in any individual organism are expressed all the time. Depending on the environmental conditions, only a limited number of genes are expressed or transcribed into mRNA and further translated to particular proteins. Therefore, analyses of DNA provide information what kind of genes are present, whereas RNA provide which genes are actually functioning among them.

When looking at prokaryotic community structures, 16S rDNA sequence data are widely used. Once the sequence of any unknown microorganism is obtained, the name of species or name of close relatives are estimated. If simultaneous analyses of both 16S rDNA and 16S rRNA are accomplished, we are able to know which microorganisms are present and which one among them are potentially active. For instance, if it is confirmed that cyanobacteria are potentially active, it suggests that photosynthesis or primary productions are going on in the environment.

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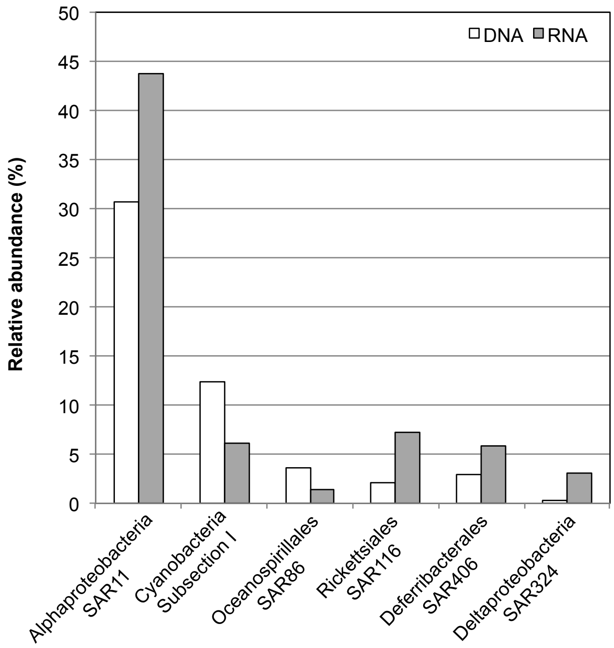


Fig. 1. Relative abundance of DNA (white bar) and RNA (gray bar) among major taxonomic groups. Box plots were calculated using relative abundance of each taxon in samples.

【Aim】

The aim of this study was to clarify the potentially active microbial communities in coastal seawater of Tohoku area by analyzing both 16S rDNA and 16S rRNA.

【What we found】

Community structures in surface layers were analyzed at a station OT6 (39º33' N, 142º83' E) locating outside of Otsuchi Bay.

Fig. 1 shows some major taxonomic groups with relative amount of DNA and RNA. The comparative analysis indicated that the relative abundances of each group were different. DNA analyses showed that biomass of SAR116, SAR406 and SAR324, were relatively small, whereas RNA contents were relatively high. So, they are quantitatively "minor groups" but potentially active. It is assumed that their biomass may be controlled by predatory processes. On the other hand, SAR11 and cyanobacteria are abundantly present at the station. As for SAR11, the

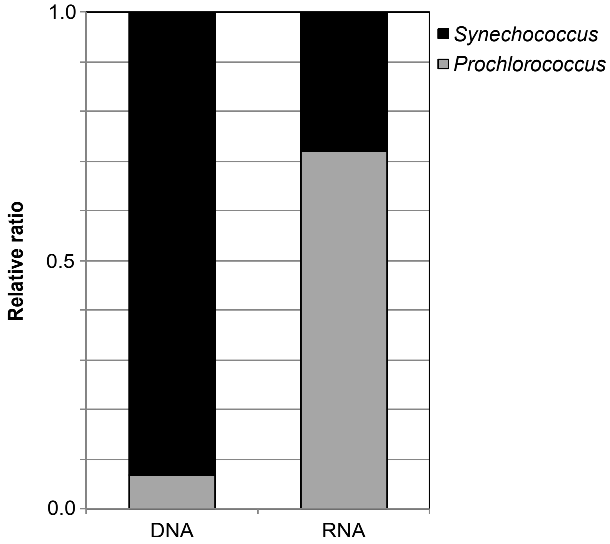


Fig. 2. Relative ratio of genus *Synechococcus* (black) and *Prochlorococcus* (gray) in Cyanobacteria Subsection I (Fig.1).

potential activity is also relatively high. Cyanobacteria, however, showed low activity compared with SAR11.

Therefore, high biomass of particular group is not always supported by high potential activity. This was further observed between genera, *Synechococcus* and *Prochlorococcus*, both belonging to cyanobacteria. DNA analyses indicated that biomass of the genus *Synechococcus* was by far dominant, whereas their potential activity was much lower than that of *Prochlorococcus* (Fig. 2). This may suggest that the latter group may be much more important as primary producers than previously thought. They are probably active and may be growing, but at the same time, they may be consumed by predators.

【Conclusion】

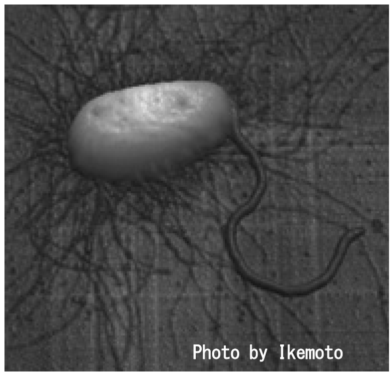
1. Simultaneous analyses of environmental DNA and RNA revealed the biomass and potential activities of some prokaryotic groups in Tohoku marine environments
2. Comparison between the members belonging to genera *Synechococcus* and *Prochlorococcus* showed that the biomass of the former was much higher than the latter, whereas, potential activity was much lower.
3. Genetic analyses offer new information of ecology of microorganisms in the ocean.

【How we investigated】

Surface seawater samples were collected during the cruise KK13-6 of R/V *Daisan Kaiyo-Maru* in September 2013. The information of the stations and environmental data were described in Shiozaki *et al*. (2015). Immediately after collection, 8 L seawater samples were passed through 20 μm and 1.6 μm pore size pre-filter (nylon mesh and GF/F filter, respectively), and then filtrated with 0.2 μm pore polyethersulfone filter. The filters were soaked RNA later solution (Ambion) and stored at -20 ºC until next procedure. Total RNA was extracted using *mir*Vana miRNA isolation kit (Ambion), and contaminated DNA was decomposed by TURBO DNA-free kit (Ambion). Total RNA were collected using Dynabeads mRNA Purification kit (Ambion), followed by polyadenylation step. Complementary DNA was synthesized PrimeScript II. 1st strand cDNA Synthesis kit (Takara). Bacterial 16S rRNA gene of V1-V2 region was amplified and pyrosequenced by 454 GS Jr (Roche).

What are marine bacteria?

Bacteria are tiny (0.5-1.0μm) organisms that can be seen only under microscopy. They distribute almost any part of this planet. In marine environments, there are approximately one million cells in surface water, and at least one thousand cells even in deep ocean. Any organic matter or pollutants introduced into the sea are finally degraded into CO_2 and water by bacteria. Therefore, their functions are essential to keep marine environment clean and sustain our biospheres. By the development of recent molecular technique, it is now possible to extract DNA directly from seawater, analyze their base sequences by so-called next generation sequencer (NGS). The sequences tell us what types of bacteria are present and what kind of functions they may exert in the sea.



【Further readings and information】

Shiozaki, T., Nagata, T., Ijichi, M., Furuya, K. (2015) Nitrogen fixation and the diazotroph community in the temperate coastal region of the northwestern North Pacific. *Biogeosciences*, 12, 4751–4764.

Some cruise data are available at;
http://www.i-teams.jp/catalog/rias/e/index.html

Bacterial communities in the coastal waters of Onagawa Bay and Otsuchi Bay of the Sanriku coastal area, Japan

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Key words: bacteria, particle-associated, free-living, 16S rRNA gene, Onagawa Bay, Otsuchi Bay

【Background】

Although invisible to the naked eye, microorganisms, especially bacteria, are essential component of marine ecosystems in terms of their huge biomass and diverse metabolic functions (e.g., decomposition of organic compounds, carbon fixation and nitrification) (cf. Castro and Huber, 2005). Previous investigations have revealed that bacteria exist everywhere in ocean but to date we are still unsure how many different types are there, what are their roles in marine ecosystems, and where are they from?

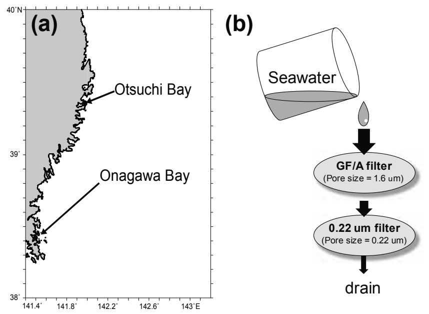

Fig. 1 Location of sampling sites**(a)**, filtering of seawater samples**(b)**

【Aim】

The objective of this study is to determine bacterial community structures of two distinct lifestyles, namely particle-associated (PA, >1.6 μm) and free-living (FL, 0.22 to 1.6 μm) in Onagawa Bay and Otsuchi Bay (Fig.1), using culture-independent methods based on the analysis of 16S rRNA gene, a taxonomic marker gene of bacteria. In addition, we predicted the sources of bacterial origin using microbial habitability database (MetaMetaDB) in order to test whether the bacterial community data can be useful as a proxy of some environmental changes in the bays (ex. influx of freshwater, increased human activity).

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【What we found】

Phylogenetic analysis of bacterial 16S rRNA gene sequences showed that three phyla, Proteobacteria, Bacteroidetes and Cyanobacteria, were the major bacterial groups in Onagawa Bay and Otsuchi Bay.

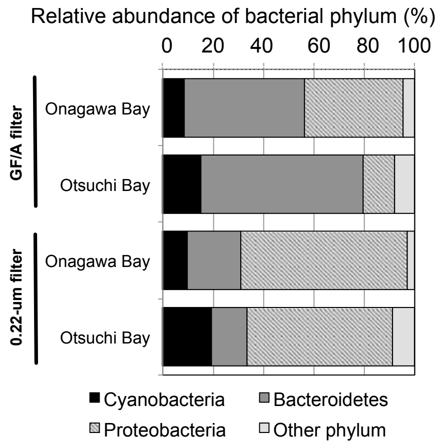


Fig.2 Bacterial community structures in samples from Onagawa Bay and Otsuchi Bay

As shown in Figure 2, phylum Bacteroidetes was abundant in PA bacterial fraction (GF/A filter), while relative abundance of phylum Proteobacteria was high in FL bacterial fractions (0.22 μm filter).

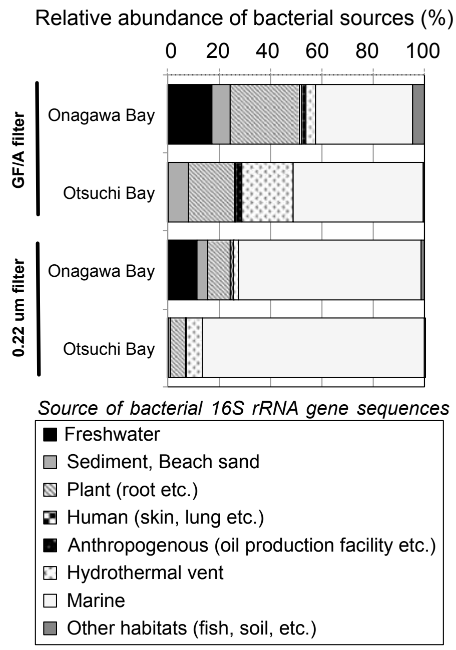
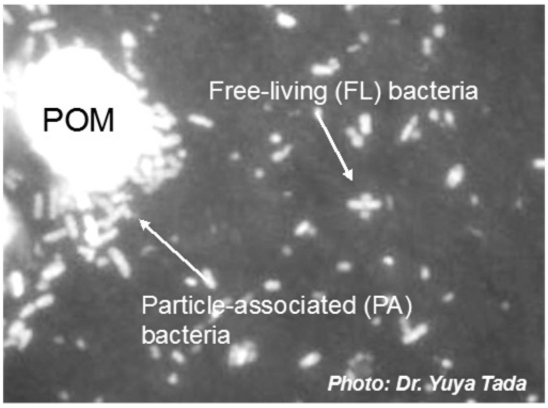


Fig.3 The potential sources of bacterial 16S rRNA gene sequences in Onagawa Bay and Otsuchi Bay

In addition, we also estimated the potential sources of bacteria in seawaters from Onagawa Bay and Otsuchi Bay (Fig. 3). Bacterial 16S rRNA gene sequences originated from marine, plant, sediment, beach sand, oil production facility and hydrothermal vent were commonly found in both bays. In addition, high relative abundances of 16S rRNA gene sequences from freshwater were observed in Onagawa Bay, indicating the introduction of bacteria from river water or rainwater into the bay after typhoon. In this study, we found that the GF/A filter fractions contained more 16S rRNA gene sequences derived from non-marine bacteria than 0.22 μm filter fractions.

Bacterial lifestyles in aquatic environments

In surface layers of the ocean, approximately half to one million bacterial cells are present in one mL of seawater. Even in the deep sea, there are at least one thousand cells /mL, so total number of bacteria in the ocean is estimated as 10^{29} cells. Those bacterial cells play important roles in the degradation of organic materials. Because there are various types of organic materials, their ecological lifestyles are divided into two major groups – particle-association (PA) and free-living (FL). PA bacteria usually attach to large particulate organic matter (POM; ex. detrital particles and fecal pellets), and they decompose POM to smaller organic molecules (dissolved organic matter, DOM). Bacteria existing as individual cells suspended in water-column is called "FL bacteria". FL bacteria use DOM as nutrient and energy sources. They convert organic carbons to CO_2. These sequential decompositions of organic matter and remineralization by PA and FL bacteria are essential in biogeochemical cycling processes in global aquatic environments.



【Conclusion】

1. Particle-associated (GF/A filter fractions) and free-living (0.22 μm filter fractions) bacterial community structures in Onagawa Bay and Otsuchi Bay were determined using 16S rRNA gene analysis.
2. Proteobacteria, Bacteroidetes and Cyanobacteria were the major bacterial groups in seawaters from both bays.
3. Bacterial community structures in PA and FL fraction were distinct.
4. Seawaters from both bays harbor bacteria originated from terrestrial environments (freshwater, plant etc.). This pattern of bacterial origin was more pronounced in the PA bacterial fraction.
5. The 16S rRNA gene sequences may act as a proxy for current natural and/or anthropogenic events in marine environments.

【How we investigated】

Seawater samples were collected from Onagawa Bay and Otsuchi Bay during KK13-06 cruise of R/V *Daisan Kaiyo-maru* (September 2013). The sampling was conducted within Onagawa Bay, close to the shore (38°25.20N–141°29.13E); samples from Otsuchi Bay were obtained close to the open water boundary at the mouth of the bay (39°21.62N–141°58.75E). These water sampling was carried out after the passage of typhoon *Man-yi*. The waters were sequentially filtered through a GF/A filter (1.6 μm particle retention size) and a 0.22 μm pore size filter to collect particle-associated and free-living bacterial fractions respectively (Fig. 1b). Genomic DNAs were extracted from each filter. Bacterial 16S rRNA gene sequences were amplified using polymerase chain reaction (PCR) and sequenced. Processing and analyses of the sequencing data were performed using mothur software package (http://www.mothur.org/). Bacterial 16S rRNA gene sequences obtained were compared with current database sequences, and the potential sources of 16S rRNA gene sequences were estimated using MetaMetaDB (http://mmdb. aori.u-tokyo.ac.jp/).

【Further readings and information】

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What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Possible transient impacts of the 2011 Earthquake on the microbial system in Otsuchi Bay

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Key words: tsunami, bacteria, viruses, inter-annual variability, Otsuchi Bay

【Background】

The earthquake and the subsequent great tsunami in Mar. 11, 2011 have been reported to have caused severe, albeit not yet fully characterized, damages to the habitats of diverse marine organisms, especially those for benthic communities along the Pacific coast of the Tohoku region (e.g. Seike et al. 2013). In Otsuchi Bay, one of the Sanriku-coast bays that were severely damaged by tsunami, particles and chemical compositions of nutrients in seawater displayed some anomalous features presumably because of tsunami (Fukuda et al. 2015). These features included high turbidity and high nitrite concentrations in summer and fall of 2011 and were suggested to be related to the tsunami-induced discharges of massive amounts of materials from land to sea. Data obtained by subsequent monitoring have revealed that these anomalous features were less evident between 2012 and 2015. Thus, the tsunami-impact on the particle and nutrient environment of the bay appeared to be transient, with a tendency of the recovery toward the pre-tsunami state (Fukuda et al. 2015).

This study was conducted to investigate whether planktonic microbial communities displayed any anomalous features in Otsuchi Bay following the great tsunami in 2011. Because microbes play a major role in regulating nutrient cycles and trophic transfers in planktonic food webs of coastal marine environments (see Box), knowledge on the variability in abundance and compositions of planktonic microbial communities following the great tsunami 2011 is essential for a better understanding of the extent and mechanism of tsunami impacts on and the subsequent recovery of coastal ecosystems in the damaged regions.

【Aim】

This study aimed at investigating seasonal variability in microbial parameters (bacteria, cyanobacteria, and virus abundances) in Otsuchi Bay in order to examine whether there were any anomalous features in the planktonic microbial system of the bay following the great tsunami 2011.

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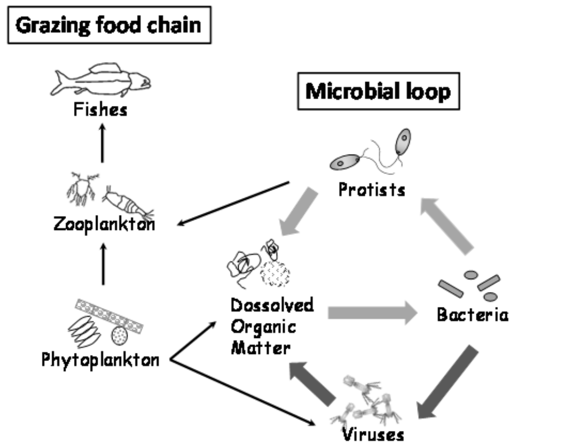
Role of microbes in material cycling in coastal marine ecosystems



In marine environments, about half of daily phytoplankton primary production is consumed by bacteria, which in turn is grazed by protists and metazoan grazers, contributing to trophic transfers. Bacteria are also lysed by viruses that infect bacteria (bacteriophages), leading to the release of bacterial cellular constituents rich in nitrogen and phosphorus. Thus, bacteria-virus interactions are important in the regulation of nutrient cycling in marine systems. Virus-to-bacteria abundance ratio (VBR) is one indicator of the strength of bacteria-virus interactions and has been a subject of intensive study in marine microbial ecology.

【What we found】

Microbes including cyanobacteria, bacteria, and viruses showed strong seasonality, which was characterized by high abundance in summer and low abundance in winter. There were significant positive correlations between microbial parameters collected during the investigation period of 4.5 years. Notably we found that the virus-bacteria abundance relationship in July and September of 2011 was strikingly different from that in the summers of the following years. The median virus-to-abundance abundance ratio (VBR) determined for July and September of 2011 was 5.6 (average ± SD, 5.8 ± 1.2, n = 34), which was significantly ($p < 0.001$) lower than the corresponding value of 12.4 (12.5 ± 2.8, n = 130) determined for July and September in 2012 to 2015 (Fig. 1). The average VBR in July and September of 2011 was also significantly ($p < 0.001$) lower than the average VBR for the data collected in other times (Nov. 2011 to Sept. 2015) of the investigation period (average ± SD, 11.2 ± 3.4, n = 407). In the literature, the average VBR in coastal waters has been reported to be generally within a range of 10–20 (Wommack & Colwell 2000), consistent with the average value that we obtained for the study period between November 2011 and September 2015. In contrast, the VBR that we determined for the period between July and September of 2011 was 2- to 4-fold lower than the typical VBR reported in the literature. These results suggest that viral abundance was anomalously low between July and September of 2011.

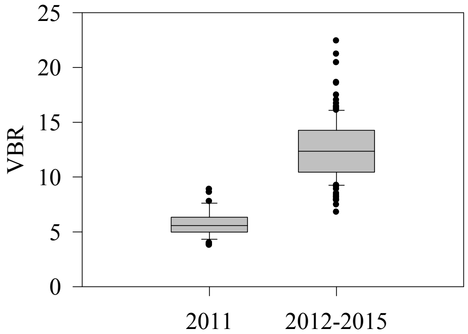


Fig. 1 Comparison of virus-to-bacteria abundance ratio (VBR) between July and September in 2011 and those in 2012–2015. Median values and 25% and 75% percentiles are given. Median values were significantly different between these two groups (Mann-Whitney Rank Sum test, $p<0.001$).

We lack the data on seasonal variability in VBR in Otuchi Bay before the great tsunami 2011. This severely limits our ability to interpret these intriguing results. Nonetheless, based on the anomalous feature of VBR relative to the data collected in the same bay during the subsequent period of 4 years and consideration of the general knowledge of VBR obtained from other coastal environments, we postulate that low viral abundance between July and September of 2011 was potentially related to tsunami-induced disturbances. One possibility is that viruses were eliminated from seawater because of the binding (scavenging) of viruses to suspended particles in seawater. Previous studies have suggested that binding of viruses to suspended particle, especially to submicron and colloidal particles, is a major loss factor of viruses in marine environments (Nobel & Fuhrman 1997). Consistent with this notion, high turbidity was observed in July and September of 2011, which was presumably due to tsunami-induced discharges of large quantities of particles from land to sea.

【Conclusions】

1) We did not detect any anomalous features in cyanobacterial and bacterial abundance seasonal variability in Otsuchi Bay even during July and September of 2011 when anomalous features in nutrient composition and turbidity have been documented in the bay.
2) Viral abundances were remarkably low in July and September 2011, yielding anomalously low VBR value of 5.8. This reduction in viral abundance, relative to bacteria abundance, might be related to the scavenging of viruses by particles in seawater. However, this effect, if any, was transient and the VBR in subsequent years was close to the typical value of VBR reported in the literature.

【How we investigated】

Samplings were conducted at fixed stations in Otsuchi Bay between May 2011 and September 2015. Sampling was conducted primarily with a bi-monthly interval. Two ml of seawater samples were preserved by glutaraldehyde (final conc. 1%), flash frozen in liquid nitrogen, and stored in deep freezer (-80°C) until analysis by FACSCalibur flow cytometry (BD).

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Genomic and metagenomic analysis of microbes in a soil environment affected by the 2011 Great East Japan Earthquake Tsunami

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Key words: Comparative genomics, Environmental microbes, Metagenomics, Siderophore, Tsunami

【Background】

The Great East Japan Earthquake of 2011 triggered large tsunami waves, which flooded broad areas of land along the Pacific coast of eastern Japan and changed the soil environment drastically. Previous studies show the tsunami-affected areas maintained high-salinity conditions for over months and there were also changes in several chemical characteristics including pH, electrical conductivity, organic matter, and heavy-metal ion. Such changes likely to have an impact on the soil ecosystem. Although many studies conducted to date investigating how such changes affect plants and microbes, the microbial characteristics of tsunami-affected soil at the genomic level remain largely unknown.

【Aim】

We aimed to investigate microbial characteristics in the tsunami-affected soil related to the microbial adaptation for the drastic environmental changes.

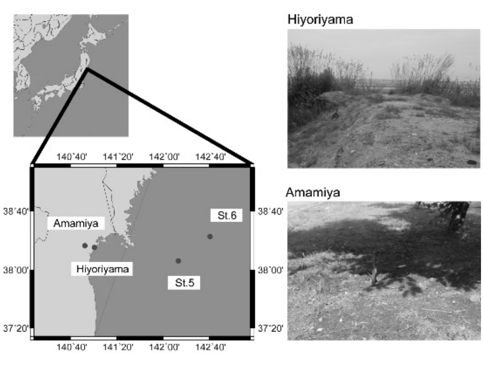

Fig. 1 A map and photos of the sampling sites in a coastal area of Sendai, Japan. The Tohoku tsunami reached Hiyoriyama, but not Amamiya

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'Genomics' and 'Metagenomics'

Typical microbial genomics studies are based on the sequencing technique through medium culture and colony isolation process. Although more than hundred thousand of microbial strains are isolated, pure cultured and collected in bio resource bank before, more than 99% of microbes remain unculturable in the laboratory mainly due to the complex culture conditions (e.g. pH, temperature, presser, gas phase, and many kinds of nutrients) and insufficient knowledge on their biology.

Metagenomics is another way to determine microbial genome sequences without cultivation and isolation process. In this manner, genomes of environmental microbes were directly extracted and sequenced, sometimes through PCR process to amplify specific genomic regions (e.g. 16S rRNA).

Although both techniques have their merits and demerits, these techniques are nowadays strongly useful ways to reveal what microbial species exist and what kinds of functional genes are present in the environment.

【What we found】

We conducted culture experiments using R2A (general low-nutrient) and ZoBell (seawater-based) media using two soil samples corrected at tsunami-affected site (Amamiya) and tsunami-unaffected site (Hiyoriyama) and two seawater sample collected at St.5 and St.6 site (Fig.1). We found Hiyoriyama site would be comparatively enriched with microbes adapted to a seawater-affected condition at 10months after the tsunami.

A greater proportion of strains isolated from the tsunami-affected soil than the unaffected soil grew in the seawater-based medium. Cultivable strains in both the general low-nutrient and seawater-based media were distributed in the genus *Arthrobacter*. We isolated four *Arthrobacter* strains from Hiyoriyama soil sample and determined their whole-genome sequences. Most importantly, whole-genome sequencing revealed independent losses of siderophore-synthesis genes from their genomes (Fig. 2). Siderophores are low-molecular-weight, iron-chelating compounds that are secreted for iron uptake; thus, the loss of siderophore-synthesis genes indicates that these strains have adapted to environments with high-iron concentrations.

Indeed, chemical analysis confirmed the investigated soil samples to be rich in iron that Hiyoriyama contained 13 times more iron than Amamiya. In addition, culture experiments confirmed weak cultivability of some of these strains in iron-limited media. There results were consistent with the independent losses of siderophore -synthesis genes.

The chemical and metagenomic analyses indicated that the tsunami-affected sample was largely similar to the unaffected sample, although some notable differences were observed regarding nitrogen metabolism and taxonomic composition that the metagenomic analyses demonstrated over-representation of denitrification-related genes in the tsunami-affected soil sample, as well as the presence of pathogenic genera (e.g. *Erysipelothrix*) and marine-living genera (e.g. *Croceibacter*, *Marinitoga*, and *Pyrococcus*) (Fig. 3) and genes related to salt-tolerance.

【Conclusion】

Collectively, the present results would provide an example of microbial characteristics of soil disturbed by the tsunami, which may give an insight into microbial adaptation to drastic environmental changes. Notably, siderophore production by soil-living microbes has been reported to help various plants absorb iron and has been associated with N_2 fixation; therefore, these observed genomic changes in the bacterial communities might also relate to plant growth. Furthermore, metagenomics analysis suggest that the tsunami facilitated microbial immigration. Further analyses on microbial ecology after a tsunami are envisioned to develop a deeper understanding of the recovery processes of terrestrial microbial ecosystems.

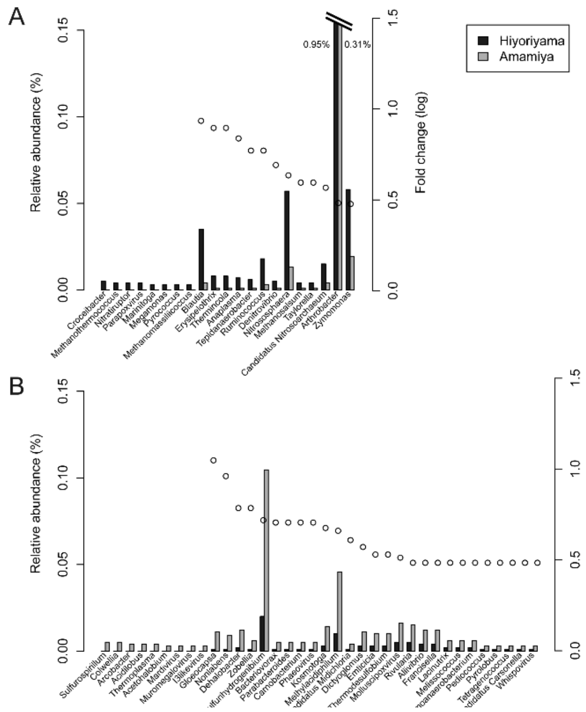

Fig. 2 Microbial genera with a substantial difference in abundance between the two sites.

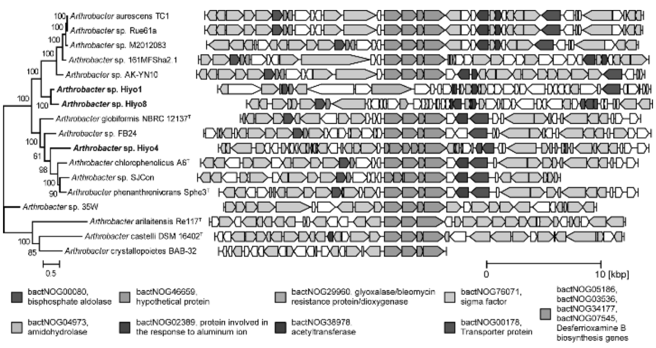
Fig. 3 Syntenic map around siderophore-synthesis gene clusters (green) in *Arthrobacter* genomes.

【How we investigated】

Soil samplings were conducted at Hiyoriyama and Amamiya in Sendai city, Miyagi, Japan, in July 2012. Seawater sampling was conducted at St.5 and St.6 off the coast of Miyagi, Japan in the Pacific Ocean, in August 2012, during the KT-12-21 cruise of R/V Tansei-Maru (JURCAOS, JAMSTEC) (Fig. 1).

R2A medium was used to cultivate microbial strains that grow under general, low-nutrient condition, and ZoBell marine medium was used to cultivate microbial strains that have adapted to a seawater-affected condition.

Four strains of the *Arthrobacter* genus that were isolated from the Hiyoriyama site and were cultivable in both R2A and ZoBell media were targeted for whole genome sequencing. Two strains (named Hiyo4 and Hiyo8) were sequenced using PacBio RS II. The other two strains (Hiyo1 and Hiyo6) were sequenced using GS FLX+ System and Ion PGM. Shotgun metagenome sequencing was performed using the GS FLX+ System.

【Further readings and information】

Satoshi Hiraoka, Asako Machiyama, Minoru Ijichi, Kentaro Inoue, Kenshiro Oshima, Masahira Hattori, Susumu Yoshizawa, Kazuhiro Kogure and Wataru Iwasaki. (2016) Genomic and metagenomic analysis of microbes in a soil environment affected by the 2011 Great East Japan Earthquake Tsunami. *BMC Genomics*, 17, 53.

Impact of the Tsunami on homing of chum salmon, *Oncorhynchus keta*, in the Otsuchi Bay

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Key words: age composition, chum salmon, homing behavior, tsunami

【Background】

Chum salmon, *Oncorhynchus keta*, return to the natal rivers using the olfaction 3 to 5 years after the birth. In Otsuchi Bay, three natal rivers flow to the inner part, and all hatcheries and natural spawning sites have damaged tremendously by the Tsunami when the fry migrate downstream in the river, resulting in death of many fry. Therefore, it has been anticipated that the number of homing adults would be low and the behavior would be defective. We have examined whether salmon can choose the natal river straightforward among a few rivers, or leave the bay to choose others, and how environmental disturbance in the river affects the homing behavior.

【Aim】

To observe the homing behavior of chum salmon in the Otsuchi Bay and the effect of an environmental disturbance on the behavior.

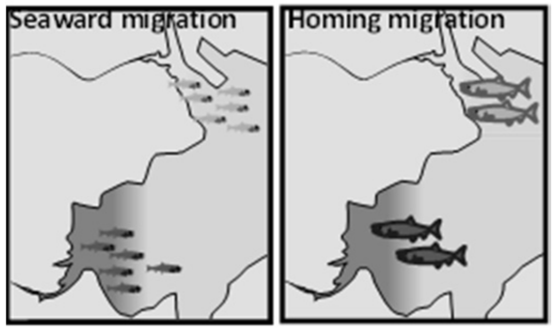
【What we found】

Annually, about half of homing salmon are four years old, and others are almost 3 and 5 years old. In 2013, however, the ratio of 3 years fish which entered the sea just before or after the Tsunami was extremely low as well as that of 4 years in 2014 (Fig. 1). On the other hand, about half of homing was 4 years in 2014 in the river that fry were artificially released even after the Tsunami.

Homing behaviors of released salmon were classified into four patterns; A) straightforward river entry, B) river entry after accesses to either river a few times, C) movement toward the bay mouth, and D) movement toward the bay mouth after accesses to either river (Fig. 2). The ratio of river entry was low in November (ca. 15%) and increased in December (ca. 50%). Nevertheless, river entry of 4 years old remained low in Dec. (ca. 28%) although the number of sample was low.

Anadromous migration of chum salmon

Chun salmon fry go to the sea just after the emergence or release in the natal river, during which they are imprinted by the specific odor of the river. After the growth in the Bering Sea and the Gulf of Alaska, an initiation of maturation triggers homing and salmon search for the odor of their natal river using olfaction in the coast. The possible candidate of the odor is an amino acid composition originated from biofilm. It has been believed that homing rate to the natal river is more than 90% in chum salmon. Therefore, an environmental disturbance in the natal river may have a negative effect on strict homing behavior.



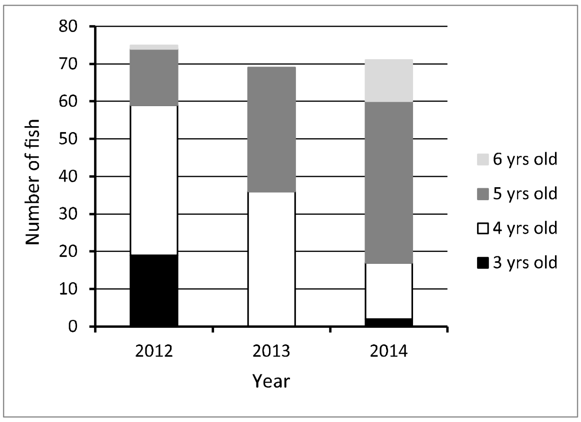


Fig.1 Age composition of homing salmon captured in the bay mouth in the winter from 2012 to 2014.

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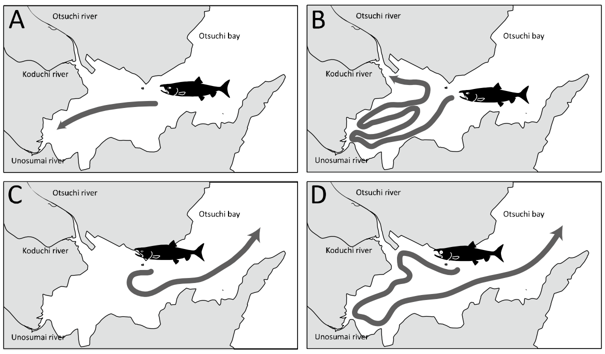

Fig.2 Imaginary pictures of 4 behavioral patterns of homing salmon in the Otsuchi Bay. (A) straightforward river entry, (B) river entry after multiple accesses to rivers, (C) movement toward the bay mouth without access to rivers, and (D) movement toward the bay mouth after accesses to rivers.

【Conclusion】

1. The homing ratio is extremely low in the generation attacked by the Tsunami.
2. In indented Sanriku coast, the homing adults search for their natal river through trial and error processes.
3. New knowledge indicates that artificial propagation largely contributes to a stable salmon catches in Sanriku area.

【How we investigated】

The ultrasonic transmitter was loaded to salmon caught in the center of bay, and released in the inner part. The acoustic signals from released fish were detected by receivers arranged in two rows, and the migration pathway was deduced based on the record. Age of test fish was determined based on the narrow space of annuli, and the maturation level was deduced using plasma concentration of sex steroid hormone. The study has been performed every winter from 2013.

Early ocean life history of juvenile chum salmon *Oncorhynchus keta* populations in the Iwate coastal ecosystem after the Great Tohoku Earthquake and Tsunami

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Key words: chum salmon, juvenile, growth, carbon and nitrogen stable isotope, offshore migration

【Background & Objects】

The Great Tohoku Earthquake and Tsunami (GTCET) occurred on 11th March, 2011. The tsunami caused more than 15 thousand deaths. And many marine products industry including salmon hatcheries were collapsed. We started to clarify the recovery process of coastal ecosystems and the life history of juvenile chum salmon in the Iwate coastal sea since 2012 in order to recover the salmon industry for cheering on peoples in the Tohoku region.

【What we found】

Juvenile chum migrated to the offshore at 90-100 mm FL in the middle May, and 70-80 mm FL in late May, 2012. Their body size and period at the offshore migration in 2012 was smaller and earlier than those before the GTCET (Fig. 1).

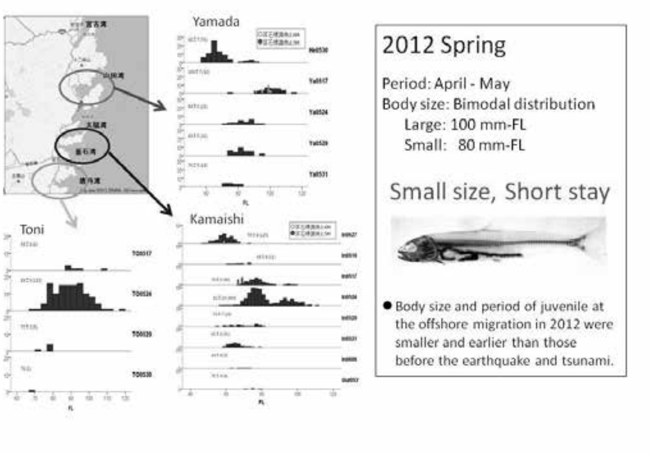

Fig. 1. Body size of juvenile chum salmon at the offshore migration during spring in 2012.

In 2013, however, juvenile migrated to the offshore at more than 120 mm in FL in the middle and late May, and 70-80 mm in FL in late May. In Utatsu of Shizugawa Bay, especially, juvenile migrated to the offshore at large (140 mm in FL) with the juvenile of small size (80 mm in FL) (Fig. 2).

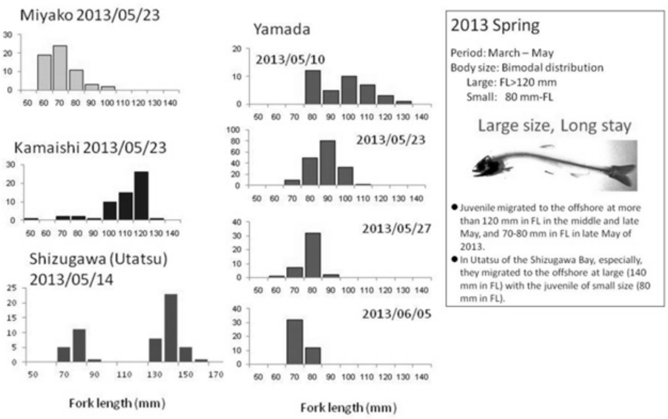

Fig. 2. Body size of juvenile at the offshore migration during spring in 2013.

The Oyashio Current in 2012 had stronger intensity and stayed shorter period than that in 2013. Seasonal changes in sea temperature at depth of 1 m of the Ohtsuchi Bay (Fig. 3) showed that the sea temperature was low during winter and early spring in years of the strong Oyashio Current such as 2008 and 2012, when juveniles reduced a growth at the offshore migration.

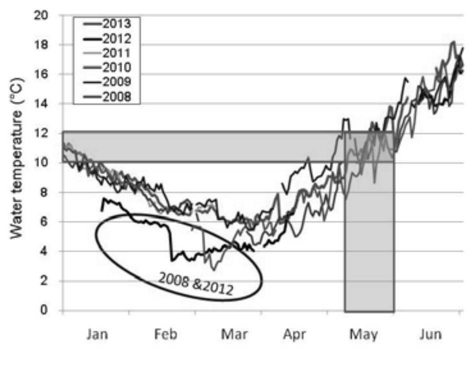

Fig. 3. Seasonal change in sea temperature (Depth of 1m) of the Otsuchi Bay in 2008-2013

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Juveniles chum salmon had -15.726±0.791‰ in $\delta^{13}C$ and 12.139±0.633‰ in their $\delta^{15}N$ in the Kamaishi Bay in the spring of 2012. Their nitrogen stable isotope was 3.8 to 4.4 ‰ higher than main prey animals (e.g., *Themisto japonica*, *Acartia clause*, and *Pseudocalanus minutes*) (Fig. 4). Their trophic level was the same as greenling, sculpin, and rock blenny, and was higher than Japanese eel, snipefish, juvenile Pacific cod, and mullet (Fig. 5). It also showed no change around the GTCET despite higher carbon stable Isotope (Fig. 6).

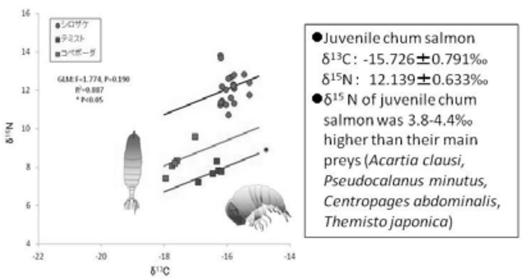

Fig. 4. Carbon and nitrogen stable isotope of juvenile chum salmon in the Kamaishi Bay in 2012

【Conclusion】

Juvenile chum salmon need sufficient body size at the offshore migration and duration of stay in the coast, which are affected by strength of cold Oyashio and warm Tsugaru currents, In the Iwate Coast. So, the monitoring offshore migration behavior of juvenile chum salmon and the dynamics of Oyashio Current in the coastal ecosystem are basically important for the evaluation and prediction of chum salmon return.

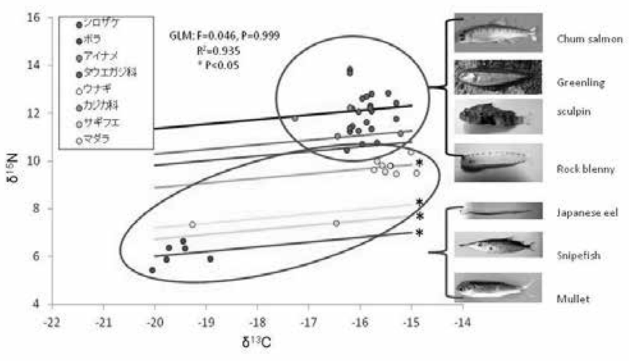

Fig. 5. Carbon and nitrogen stable isotope of juvenile chum salmon and other animals

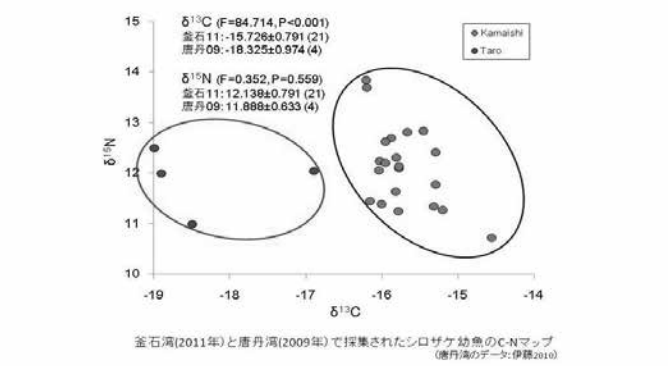

Fig. 6. Relationship between carbon and nitrogen stable isotope of juvenile chum salmon collected at Toni Bay in 2009 and at Kamaishi Bay in 2012. (Data source in Toni Bay: Ito 2010)

Forthermore, the ecosystem-approach sustainable management consisting of the adaptive management and the precautionary principle is extremely important for the salmon fisheries industry and the human society in the Sanriku Coast. The adaptive management should be executed based on the feedback control between monitoring and evaluation, consensus-building system, and accountability to stakeholders.

【How we investigated】

We surveyed growth and trophic condition of juvenile chum salmon collected by a lamp-balanket net in Iwate coastal seas, using analyses of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope. We evaluated change in body size of juvenile at an offshore migration using the measurement of body size and scale analysis in 2012-2013.

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Changes in the plasma sex steroid levels of chum salmon returning to the Otsuchi Bay during the home migration period

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Key words: chum salmon, Otsuchi bay, steroid hormones, reproduction

【Background】

The earthquake off the Pacific coast of Tōhoku in March 11 2011 caused serious damage to salmon aquaculture. It was one of the greatest earthquakes on record and the effects of the tsunami on the ecosystem inhabited by salmon are unpredictable. Otsuchi Bay in Iwate is one of the bays that was severely damaged by the tsunami. It is unclear if the ecosystem has been irreversibly altered or if it can recover to pre-tsunami condition.

In Otsuchi, salmon typically start returning in mid-September and the run ends in January. When the Otsuni hatchery collects salmon eggs for fertilization from the fish that return in September and October, fish are kept in a freshwater pool for about two weeks to obtain fully matured eggs. We empirically know that the salmon returning in September and October are not fully mature. However, physiological information on the maturational status of salmon of Otsuchi Bay is lacking. Thus, establishment of basic information on reproductive status is important to assess the effects of the earthquake and tsunami.

In the present study, we collected wild chum salmon returning to Otsuchi Bay from 2012 to 2014 and measured changes in plasma testosterone, estradiol-17β (E2), 11-ketostetosterone (11KT) and 17α,20β-dihydroxy-4-pregnen-3-one (DHP) (Fig. 1). In salmonids, E2 and 11KT are considered to have important roles in the regulation of oogenesis and spermatogenesis, respectively (Nagahama 1994). DHP has been identified as a natural maturation-inducing hormone for oocyte and sperm (Nagahama 1994). In salmonids, plasma E2 levels in female and plasma 11KT levels in male typically start increasing in early gametogenesis, peak in mid-gametogenesis, and decrease in late gametogenesis. Conversely, plasma DHP levels in both females and males increase when final maturation of gonads takes place. Levels of those sex steroids reflect the status of the maturation.

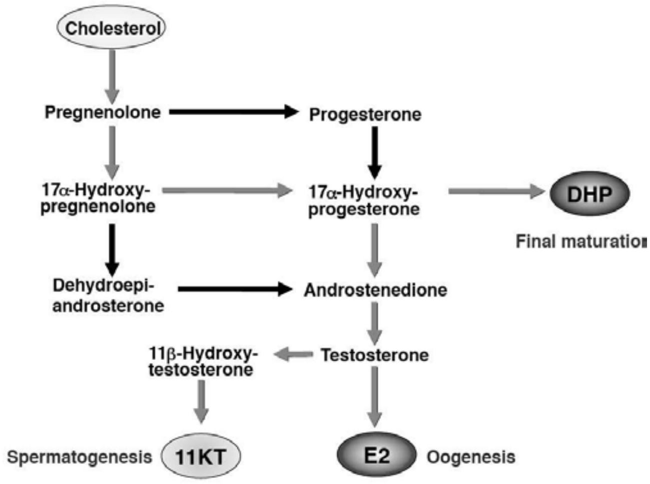

Fig. 1 Steroidogenic pathways in salmon

【Aim】

[1] To obtain basic information on sex steroid levels of chum salmon of Otsuchi Bay from October to January.

[2] To evaluate effects of tsunami on physiological status (e.g. gonadal maturation) of Ostuchi chum salmon.

【What we found】

Plasma E2 in females (Fig. 2) and 11KT levels in males (Fig. 3) between October and November were generally high and plasma DHP levels increased in December (Fig. 2 and 3). The pattern of change in sex steroid levels was typical of salmonids during late gametogenesis and final maturation stages. Interestingly, most of the chum salmon collected in December were ovulated even though they were in seawater. This is in contrast to chum salmon in the Ishikari and Chitose Rivers in Hokkaido, which undertake a much longer journey to their spawning ground. Typically, Chitose River chum salmon are not fully mature before entering the river (Ueda 1998).

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【Conclusion】

These results indicate that salmon in Otsuchi Bay between October and November were not fully mature and the majority reached full maturation stages in December. Therefore, keeping adult salmon for fertilization in September and October in a freshwater pool for a few weeks is a reasonable solution for fish to achieve full maturation. How the early returns behave in Otsuchi Bay until they reach full maturity is an intriguing question that needs addressing.

There was no obvious difference in the patterns of plasma steroid levels in Otsuchi Bay during thee years of sampling (2012 to 2014). These results partially provide evidence that the impacts of the earthquake and tsunami on their reproductive status were minimal.

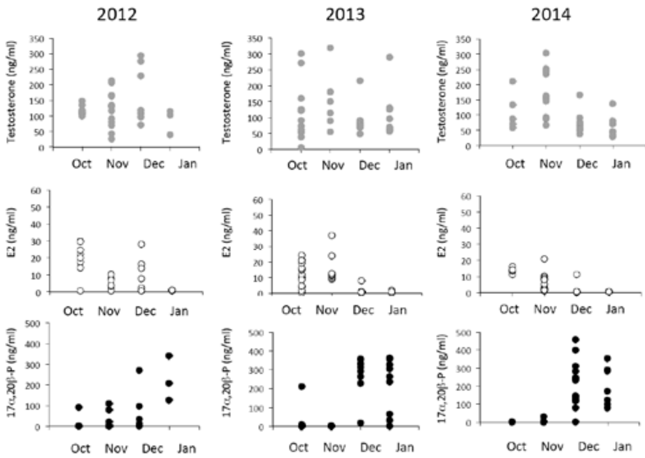

Fig. 2 Plasma sex steroid levels in female chum salmon

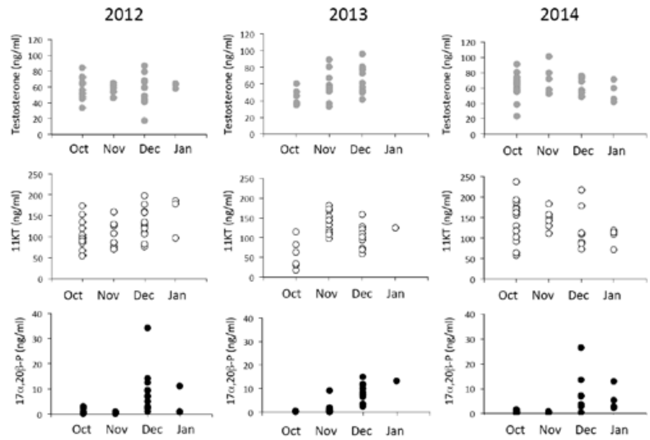

Fig. 3 Plasma sex steroid levels in male chum salmon

【How we investigated】

We collected plasma samples from wild salmon returning to Otsuchi Bay between October and January from 2012 to 2014 (female total n=109, 3.67 ± 0.11 kg of body mass, male total n=97, 3.53 ±0.12 kg of body mass). Each month, we caught twenty adult chum salmon by fixed nets, which were located at Nojima or Nakanoshima in Otsuchi Bay. Fish were then euthanized using an overdose of buffered MS222 (130 mg/L). Blood samples were immediately collected on the fishing boat using EDTA-K syringes. Blood samples were centrifuged at 4°C at 3,000 rpm for 10 min, and plasma was removed and frozen until analysis. Plasma T, E2, 11KT and DHP levels were measured using enzyme immunoassay kits (Cayman Chemical, Ann Arbor, MI, USA).

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What happened to the marine environments after Great East Japan Earthquake？
TEAMS International Conference, March 2016

Feeding environment of juvenile Japanese flounder *Paralichthys olivaceus* along the northern Iwate coast

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Key words: mysid, settled juveniles, stable isotope, stock enhancement

【Background】

Japanese flounder, *Paralichthys olivaceus*, occur all over Japan, and is important species for fisheries with its high commercial value. The stock size of this species determined mainly by the survival at larval and juvenile stages. After the settlement on shallow coastal water, juveniles mainly utilize mysids as initial food item. They shift their food item from mysids to fish larvae as they grow. The feeding success ensures the growth and the survival of this species.

The inspections on stomach contents are commonly used to determine food items and evaluate feeding success. But the method supply only "snapshot" information of stomach contents when the fish caught. Recently stable isotopes are often used to determine food sources, as they reflect history of feeding with certain turnover rate. Moreover we can estimate the contribution from each food source numerically.

In Iwate prefecture, the stock assessment on this species has revealed low fishing effort and resultant low exploitation rate after Tsunami disaster enhanced spawning stock biomass (SSB) of this species. The recent high SSB was considered to produce relatively high recruitment despite of lower recruitment per spawner (RPS), namely lower overall survival rate from spawning to recruitment, comparing with lower SSB but higher RPS in some years before the Tsunami.

In spite of the successful monitoring of stock dynamics on this species in Iwate prefecture before and after the Tsunami, detailed mechanism and factors affect the survival in early life stage of this species are yet remain unrevealed.

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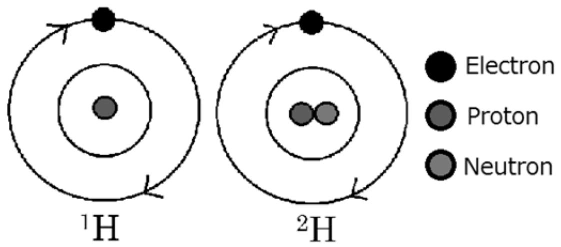
What are stable isotopes?

Isotopes are different types of atom of same element, have same number of protons, but have different number of neutrons. Two types of isotopes exist, radio active and stable isotopes. Light elements which constitute organisms like H, C, N, O and S are often used for isotope study on organisms. Hydrogen, as an example, includes lighter 1H and heavier 2H (D). Isotopes react differently due to the difference of mass of the isotopes in chemical, physical and biological processes. Therefore we can use stable isotopes as tracers.



【Aim】

This study aimed to develop the method to evaluate the feeding success of settled juvenile Japanese flounder on Iwate coast to compare before and after the Tsunami in March 2011.

【What we found】

We compared density of mysids, stomach contents of settled juvenile Japanese flounders, stable isotope ratios of both mysids and settled juvenile Japanese flounders before and after the Tsunami with 2009 and 2012 data. The numbers of settled juveniles in August were high in 2012, but low in 2009.

In 2009 the density of mysids in the environment was highest in late August. The amounts of mysids in the stomachs of the juveniles were also observed to be large. After that the dependence on fish larvae as food items gradually increased based on the stomach contents inspections.

On the other hand in 2012 the density of mysids in early August was high but low in late August. In late September the highest density of mysids was observed. The dependence on mysids of the juveniles was observed to be high in early August and also in late September. The large amounts of fish larvae were observed in the stomachs of juvenile Japanese flounder in late August, but not in late September.

From the stable isotope analysis of juvenile Japanese flounders, both the nitrogen and carbon stable isotope ratios increased with the growth of juveniles. These ontogenic shifts of stable isotope ratios were related with (1) the temporal shifts of stable isotope ratios of mysids and (2) the increased dependence on fish larvae.

The mysids are considered to partly depend on micro-phytobenthos (MPB), which have more enriched carbon stable isotopic signature than phytoplankton. The carbon stable isotope ratios of mysids in Kyoto prefecture, along Japan Sea side of Japan were reported to be higher than in northern Iwate prefecture. This observation suggested the availability of MPB in northern Iwate was lower than in Kyoto, and increased from August through October in northern Iwate, which might cause the temporal shifts of stable isotope ratios of mysids.

【Conclusion】

1. The nitrogen and carbon stable isotope ratios of mysids, major prey organism for settled juveniles of Japanese flounder, increased from July through October.
2. The stable isotope ratios of the settled juveniles of Japanese flounder changed with the increase in stable isotope ratios of mysids. And the ratios also changed as the juveniles shift their prey organisms from mysids to fish larvae.
3. The carbon stable isotope ratio of mysids in northern Iwate coast was lower than in other area, which might suggest that the availability of MPB in this area is lower than in other area.

【How we investigated】

We conducted sampling in Noda bay, northern Iwate prefecture, on settled juveniles of Japanese flounder using NRIFE II beam trawl, and also on prey organisms using Hirota's sledge net monthly from July through October. We measured the body size and weight of the collected juvenile Japanese flounders, and examined stomach contents of them. The prey organisms collected from environmental waters were sorted in three categories fish, mysids and other crustaceans. And the fish and mysids were classified at species level. The tissue of juvenile Japanese flounders and prey organisms were dried and were grounded to fine powder. The nitrogen and carbon stable isotope ratios were determined by EA/IRMS. The contribution from each food source was estimated based on the stable isotope ratios with two sources mixture model.

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Evaluation of the genetic diversity of the marbled flounder in Sendai Bay

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Key words: genetic diversity, marbled flounder, Sendai Bay, stock management

【Background】

Stock management requires the information on genetic diversity, because it provides the direct knowledge about the organisms of interest such as population structure, migration rates between populations and population sizes. Genetic diversity can be, however, affected by environmental and demographic changes, so it should be carefully investigated, especially where dramatic disturbances have occurred.

Marbled flounder *Pseudopleuronectes yokohamae* is a commercially important fish over north Japan (Fig. 1). In Sendai Bay, the population of this species is considered as a single management unit, and its spawning ground has been protected for stock conservation. As the Sendai Bay population has been likely influenced by the great tsunami occurred in 2011, the genetic diversity needs to be examined for stock management.

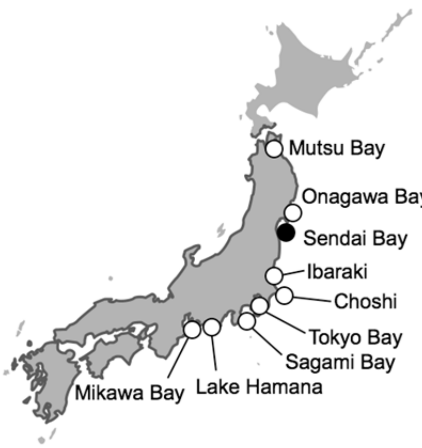

Fig. 1 Distribution of the marbled flounder (grey lines) and sampling localities in this study. The black circle shows Sendai Bay. Boso Peninsula locates between Choshi and Tokyo Bay.

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【Aim】

To evaluate the tsunami impact on the genetic diversity of the marbled flounder in Sendai Bay by the population genetic analyses using microsatellite DNA markers.

【What we found】

Significant genetic divergence was observed between the east and west sides of Boso Peninsula, in which populations further diverged (pairwise F_{ST} = 0.02305 – 0.19784; Fig. 2). Among the populations collected from the east side of Boso Peninsula, the Mutsu Bay population was differentiated (F_{ST} = 0.03829, P < 0.001) and gene flow was found over the wide area from Onagawa Bay to Choshi including Sendai Bay.

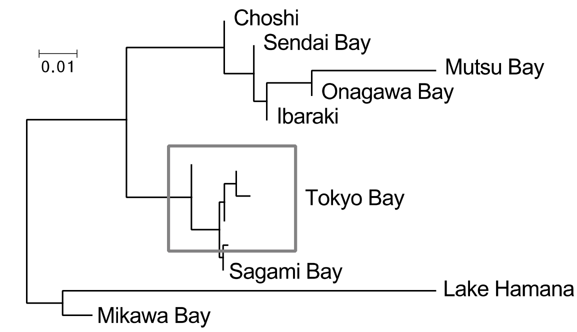

Fig. 2 Genetic relationship among the populations of the marbled flounder based on F_{ST} values.

The genetic variation of the Sendai Bay population did not demonstrate any dramatic changes in time (H_E = 0.5061 – 0.5463) and was rather higher compared to those of the western populations of Boso Peninsula (H_E = 0.3817 – 0.4557).

【Conclusion】

1. The Sendai Bay population is included in a single management unit ranging from Onagawa Bay to Choshi.
2. No signal of genetic bottleneck was detected in the Sendai Bay population.
3. The tsunami impact on the genetic diversity of the Sendai Bay population is considered to be minor but a long-term monitoring may be needed.

【How we investigated】

Temporal change in genetic diversity after the tsunami impact was investigated using thirteen populations collected in Sendai Bay from April 2012 to February 2014 (N = 807). Nine populations from the Pacific Ocean coasts (Mutsu Bay, Onagawa Bay, Choshi, Tokyo Bay, Sagami Bay, Lake Hamana, Mikawa Bay; N = 596; Fig. 2) were also analyzed for comparisons. Using genomic DNA extracted from fin clips, genotyping was performed at sixteen microsatellite loci, which we previously developed from the genomic data of this species, and population genetic analyses were conducted.

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Research for the restoration of ascidian aquaculture in Samenoura Bay

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Key words: Ascidian, aquaculture, Samenoura

【Background and Aim】

An ascidian is a major aquaculture species like as a scallop, oyster and undaria seaweed in Sanriku coasts, especially in Miyagi Prefecture. Unfortunately, these aquaculture industries were almost destroyed due to the great disaster of March 11, 2011. Samenoura Bay in Miyagi was the best production of Japan, however the present production of an ascidian was few because it takes three years over that they became the market size (Fig 1). Further, there was the most important as a supply area of the wild ascidian spats. It is thought that the population of the aquaculture ascidian contributes to the collection of the seeds in Samenoura Bay.

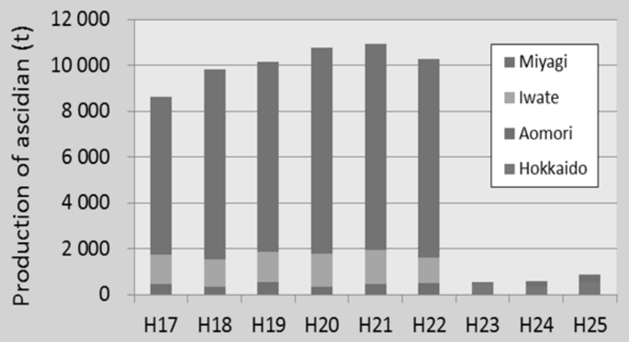

Fig 1. Production of aquaculture ascidian from 2005 to 2013 in all of Japan.

On the other hand, a wild population of young and adult ascidian was found to live in the Samenoura Bay immediately after the disaster. Therefore, we observed the appearance situation of eggs and larvae in the Bay, and investigated the distributed quantity of the ascidian to estimate the existence quantity of wild resources in Sameunora Bay, and tried to research the effective spat collection from wild populations of ascidian.

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【What we found】

The numbers of ascidian eggs and larvae decreased in comparison with before the disaster, but have begun to recover since the third year after the disaster (Fig 2).

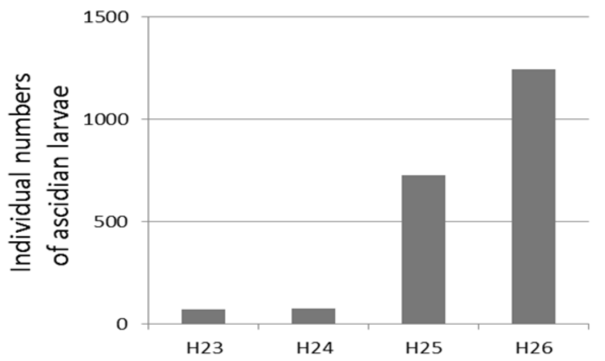

Fig 2. Changes of the number of ascidian larvae collected using plankton net in Yagawa sampling site in Samenoura Bay .

The large outbreak of the wild ascidian in Samenoura Bay observed from the third year after the disaste (Photo 1 & Fig 3).

From the observation of the seawater flow condition, the flow of the Bay was counterclockwise with the average speed of 1-3 cm/s, and the water entered from the upper layer and flowed out from the lower layer.

【Conclusion】

The wild ascidian population which occurred in large quantities after the disaster was suggested to be contributed to the increase in number of ascidian larvae from the third year after the disaster, because the aquaculture ascidian in the Samenoura Bay had not yet matured. And so, it is thought that the aquaculture populations contributed to reproduction in addition to the wild population from the fourth year after the disaster (Photo 2).

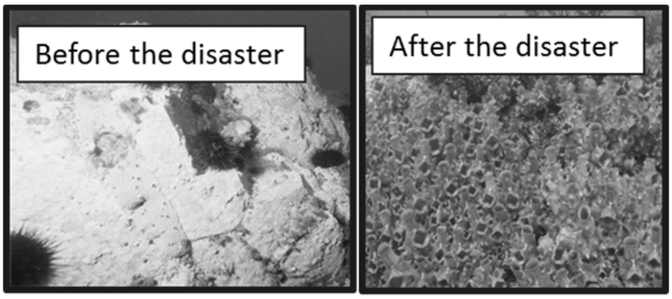

Photo 1. The large outbreak of the wild ascidian population in Samenoura Bay.

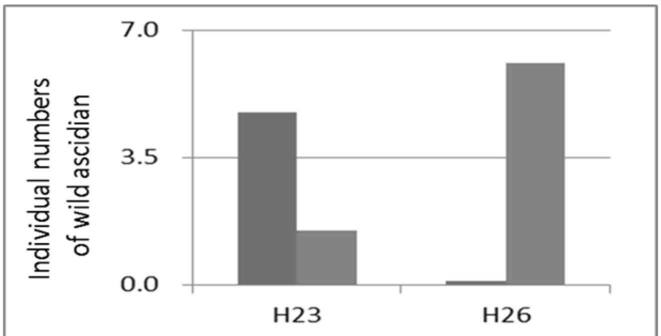

Fig 3. Individual numbers of the wild ascidian distributed at the Chidorishima area in Samenoura Bay

Based on the data of the flow, we performed particle diffusion simulation and predicted some collecting areas of ascidian larvae. As the result of the spat collecting test of ascidian larvae, we would be able to collect the ascidian seeds effectively.

【How we investigated】

From 2012 to 2015, we have been conducted an investigation into the eggs and larvae appearance at the seedling areas of Yagawa offshore in Samenoura Bay during the winter spawning season of December to February. Also, we observed a direction and the speed of the flow of the seawater in the bay. Based on the observation result, we performed the larval diffusion simulation of the ascidian during spawning season (Fig 4).

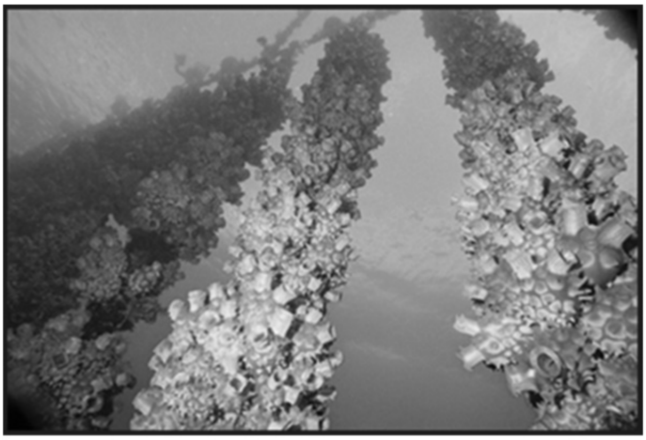

Photo 2. Aquaculture ascidian grew up to a matured size.

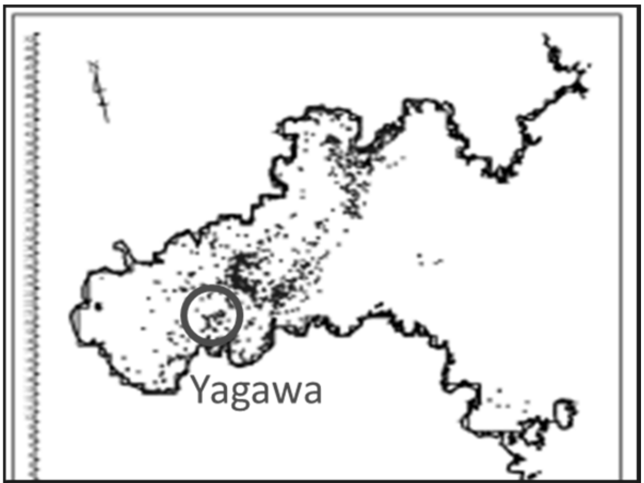

Fig 4. Diffusion prediction of ascidian larvae as a particle during the spawning season from December to Febraury.

【Further reading and information】

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Fisheries-based evaluation of carrying capacity for scallops in Ogatsu Bay

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Key words: scallop, farming production, growth, food availability

【Background】

Scallop farming is one of major aquaculture industries in the Sanriku coast of northern Japan. The earthquake and tsunami on March 11 in 2011 brought devastating losses in the scallop culture as well as oyster, sea squirt and marine alga etc. In the process of recovering and reconstructing the aquaculture farm lost by the natural disasters, evaluation of environmental carrying capacity in each farming site is an essential task to guarantee a sustainable production of filter feeders like a scallop in the future. We focused on a transition of scallop farming by ear-hanging method after the disaster in Ogatsu Bay that predominantly produce scallops and is recovering began first in the coast of Miyagi prefecture. Therefore, we hereby monitored aquaculture environment and investigated scallop productivity with growth characteristic.

【Aim】

To understand the environmental carrying capacity for scallop farming in Ogatsu Bay, productivity based on the number of facility and annual production in the bay and growth state (e.g., size, weight and indices of organ) were investigated and compared to pre-quake state. The carrying capacity is considered by food availability based on a primary production.

【What we found】

The number of facility for scallop farming and the annual production of the farmed scallop in Ogatsu Bay recovered to about 66% and 76% in 2014, respectively, compared to the data in 2010 (before the earthquake disaster). The productivity of scallop, which was calculated as an amount of production per rope where scallops were ear-hanged, 2014 showed at 23.7 kg per rope lower than 30.9 kg per rope shown in 2013, even though the annual productions in 2013 and 2014 were almost the same. Total amount of chlorophyll a (above 20 m depth) throughout a year did not differ between 2014 and 2013 suggesting the same fluctuation level of the primary production as past. In 2014, the low-growth scallops (i.e., shell size, soft body weight) cultured in deeper layer was observed at two different farming sites as previously found before the earthquake in 2010. The adductor muscle index (adductor muscle weight (g)/whole soft body weight without gonad (g) *100) was kept at about 38 in both layers higher than previous level before the earthquake (Fig.1).

【Conclusion】

1. A food availability for good growth of scallop was not sufficient for the scallops farmed in deeper layer in Ogatsu Bay in 2014.
2. It may be a time that the producers need to re-consider and regulate the amount of production to accomplish a sustainable and efficient production of scallop as a filter feeder on the basis of environmental carrying capacity estimated in Ogatsu Bay.

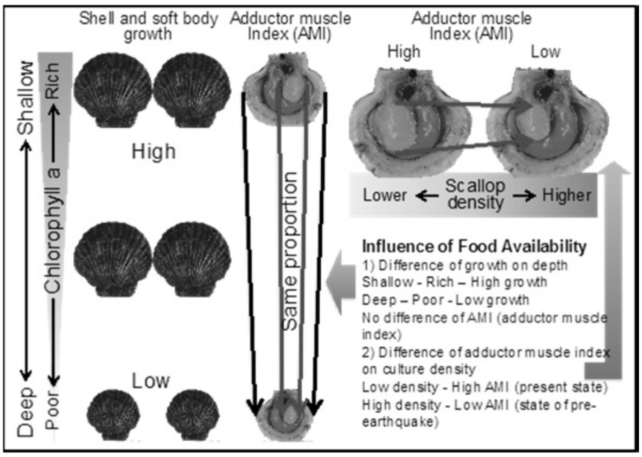

Fig.1 Present state of productivity and growth characteristic of scallop farming in relation to food availability and scallop density in Ogatsu Bay.

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【How we investigated】

The growth state was calculated as a production amount per rope based on the number of facility and annual production in the bay and compared to pre-quake level. In parallel with it, the scallops farmed by ear-hanging method at two farming sites of Ogatsu Bay were also used for another estimation of growth state. Shell size, weight of softbody and indices of each organ was evaluated and compared to the pre-quake data. The environmental capacity for scallop culture in Ogatsu Bay was considered by growth state and food availability based on a primary production.

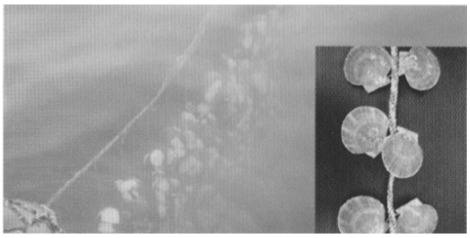
【Further readings and information】

Research plan “Environmental capacity of cultured scallop in Ogatsu Bay” Please visit the web site for details;
http://www.i-teams.jp/catalog/plan_result/metadataDisp/0097_P01?lang=en&view=detail

Research result “Environmental capacity of cultured scallop in Ogatsu Bay” Please visit the web site for details;
http://www.i-teams.jp/catalog/plan_result/metadataDisp/0097_R01?lang=en&view=detail

How are scallops cultured?

Scallop inhabits the sandy seabed of 10-30 m depth in northern Japan in nature. Most of scallop is cultivated through sowing culture or hanging culture using natural seeds. In Ogatsu bay, an “ear hanging method” is employed for hanging culture facilities of scallop. Scallops spawn egg and sperm in early spring and then the fertilized eggs develop into planktonic larva. After over a month of planktonic life, the larva attach by byssuses to seed collector made of synthetic fishing nets. The settled larva on the collector is termed spats. The spats grown up to 10 mm are dissociated from collector and harvested. The harvested scallop seeds are cultivated by hanging methods up to commercial size for over a year.



Ear-hanging method, see Suisanzoushoku System 4, Kouseisha-kouseikaku, 2007

Development of GnRH-induced artificial maturation technique for scallop

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Key words: GnRH, bivalves, reproduction, neuroendocrinology, hormones

【Background】

Aquaculture production of marine bivalves (e.g., Japanese scallop, Pacific oyster, Manila clam, surf clam, bloody clam) is an important industry in Tohoku coast and it has been maintained at stable production level. However, the 2011 off the Pacific coast of Tohoku Earthquake with tsunami caused large-scale disappearance of the farming sites and natural habitants of above marine bivalve species. To recover the aquaculture production of those marine bivalves effectively, it will be a key point to manage their broodstock to produce the seeds for uses of shellfish farming and releasing to natural environment. Nevertheless, the technique of artificial maturation for bivalves has yet to be developed well although serotonin (5-HT) treatment is known to stimulate spawning in bivalves.

【Aim】

To develop a method that can stimulate the gonad development in bivalves, we focused Gonadotropin Releasing Hormone (GnRH) as a tool of hormonal treatment. Japanese scallop (*Patinopecten yessoensis*) is selected as a model bivalve species for above hormonal treatment since its organs (e.g., gonad) are separated and easy to observe maturation stage without dissection. Although invertebrate GnRH function in reproduction is still unclear, this study aimed to elucidate the effect of GnRH treatment in bivalves.

【What we found】

We previously identified full-length GnRH gene and peptide sequence from Japanese scallop by cDNA cloning and mass spectrometry, respectively. *In vitro* culture study revealed that GnRH showed spermatogonial proliferation activity. We hereby conducted GnRH peptide administration into scallop gonad in order to analyze the GnRH function related to reproduction *in vivo*.

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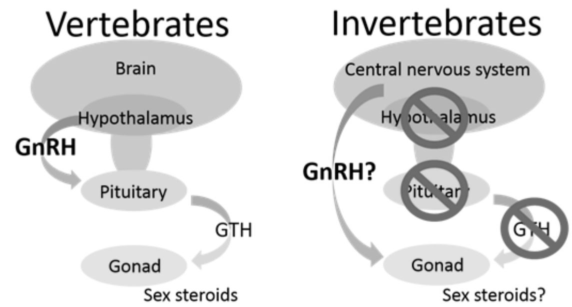
In this study, we hereby developed slow-release peptide delivery system with scallop gonad and were able to observe long-term effect of GnRH administration (i.e., 6 weeks). This study found that GnRH peptide administration influenced gonad development in scallop during a reproductive phase. Specifically, this GnRH administration could promote gonad development for testis with an increase in the number of spermatogonia and GI. On the other hand, an inhibitory effect of this administration was seen on oocyte growth.

Invertebrate GnRH

Gonadotropin-releasing hormone (GnRH) is the neuropeptide hormone that controls reproduction in vertebrates. Up to the present, GnRH genes have been found in a number of invertebrate species, indicating that the common ancestor of protostomes and deuterostomes possessed GnRH-signaling system. However, whether the GnRH like molecules in invertebrates have reproductive functions gametogenesis has yet to be determined.



GnRH regulation for reproduction through hypothalamic-pituitary-gonadal axis in vertebrate.

【Conclusion】

1. The *in vivo* GnRH administration accelerated spermatogenesis with an increase in the number of spermatogonia and GI in the males.
2. This administration inhibited oocyte growth in the females.

【How we investigated】

We prepared emulsion mixture of cacao butter with synthetic peptide of scallop GnRH and injected molten emulsion into the scallop gonad. The injected emulsion was immediately solidified and remained for at least 6 weeks in the gonad. All injected scallops were reared for 6 weeks in net cages hanged from the buoy at Onagawa Bay. Then, the gonad and soft body weight were measured in 2, 4 and 6 weeks for calculating gonad somatic index (GI) as an indicator of gonad development status. The gonad was fixed with 10% formalin solution and embedded in paraffin wax. Paraffin sections were prepared for histological analysis for measurement of oocyte diameter in ovary and count of spermatogonia. All data were statistically analyzed.

【Future direction】

Each mollusk including bivalve may have original GnRH function. Hence, we plan to investigate in vivo administration with other bivalves and species-specific GnRH peptide in order to uncover a common functional mechanism of bivalve GnRH and to develop the universal technique of GnRH-induced artificial maturation for any marine bivalves, which are commercially important in Tohoku coast.

【Further readings】

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A novel method for DNA extraction from bivalves

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Key words: Ark shell, Pearl oyster, Pacific oyster, Metabolome

【Background】

Considering fisheries reconstruction and future sustainable yield of fisheries, genetic analysis based on DNA sequences are essential tool for the stock management and the conservation of biological diversity in fish and shellfish. In bivalves, the genetic analysis is often employed for investigating population structures, species identification and the evaluation of genetic diversity. On the other hand, a problem in the genetic analysis of bivalves is that most specimens must be killed and/or seriously injured to open their shells for collecting the tissue using for DNA extraction. The problem makes difficult to access the genetic analysis of the threatened species, rare lineage made by the breeding and expensive species.

To solve this problem, we attempted to establish a new method for the DNA extraction from bivalves without injury. Most bivalves are completely covered with their shells and they always retain water in their mantle cavity. When the habitats dry up, bivalves close the shells and body wastes release into the water filling the mantle cavity. We hypothesized the DNA is also contained in these body wastes in the mantle cavity water (MCW). Thus we tried to extract DNA from MCW using four commercial species, *Anadara broughtonii*, *Pinctada fucata martensii, Ruditapes philippinarum* and *Crassostrea gigas* (Fig. 1) in the current study.

【Aim】

To establish a new method for DNA extraction from bivalves without injury using mantle cavity water.

【What we found】

The brief method of the MCW extraction is illustrated in Fig. 2. Because the body wastes

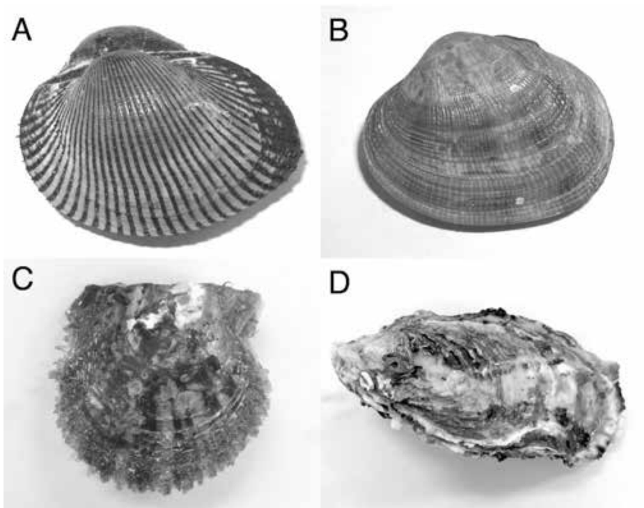

Fig. 1. Four bivalve species used in this study. (A) *Anadara broughtonii*, (B) *Ruditapes philippinarum,* (C) *Pinctada fucata martensii* and (D) *Crassostrea gigas.*

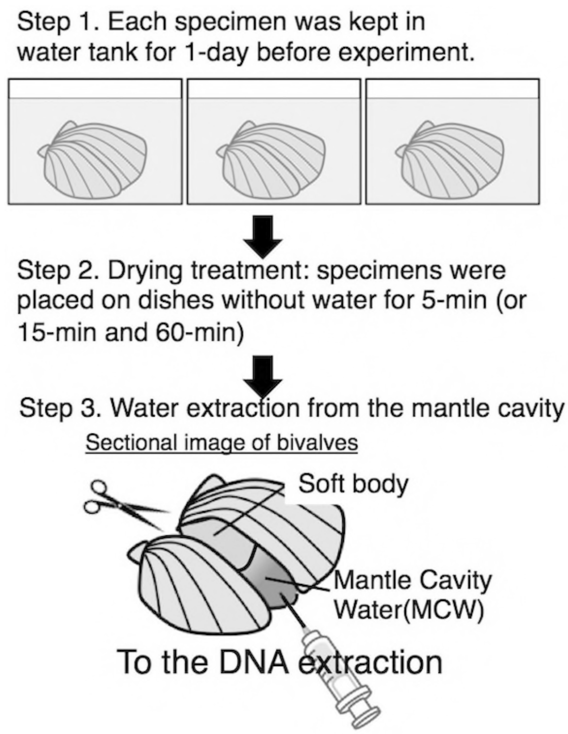

Fig. 2. Brief illustration of the method for drying treatment and MCW extraction.

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containing DNA probably accumulates in the MCW as time proceeds, firstly we confirmed the optimal time of drying treatment using *A. broughtonii*. We conducted drying treatment for 5-min, 15-min and 60-min, then extracted the MCW, respectively. PCR amplifications using extracted DNA from each MCW showed amplified DNA fragments (mtDNA CO1 region; approximately 750-bp) and no difference in the concentration of PCR products between drying treatment times (Fig. 3A). Thus we adopted 5-min drying treatment before MCW extraction. Then we amplified DNA fragments of three genes (mtDNA; CO1, nuclear DNA; H3 and LSU) using four bivalve species. As a result, all DNA fragments successfully amplified in all species (Fig. 3B). To confirm whether contaminations of DNA from other organisms such as symbionts occur, amplified DNA fragments were sequenced and consistent with the sequence of each bivalve species, registered in the database.

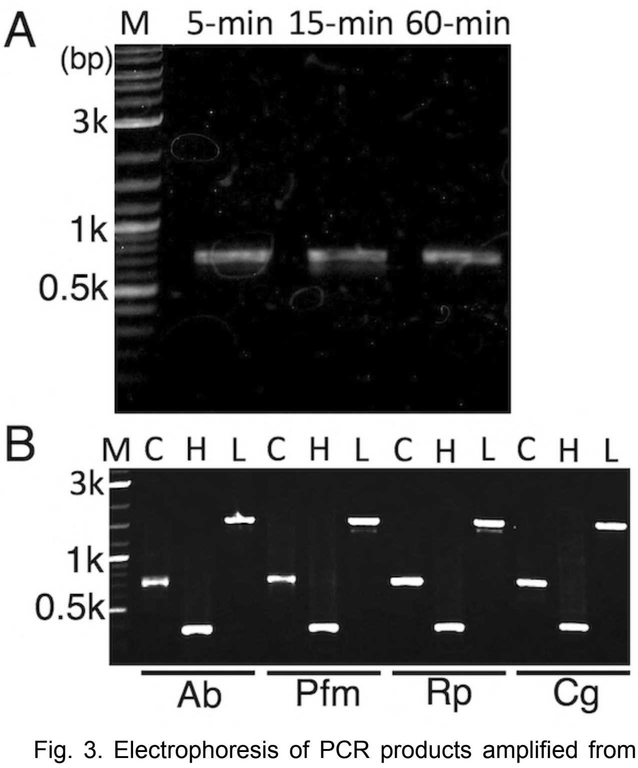

Fig. 3. Electrophoresis of PCR products amplified from DNA extracted from the MCW. (A) PCR products of CO1 region *A. broughtonii* treated 5-min, 15-min and 60-min. (B) PCR products amplified from 4 bivalve species DNA extracted from MCW. M, C, H, L indicates Marker, CO1, H3, LSU, respectively.

In the current study, we provide first evidence that DNA can be extracted from the bivalve MCW. Because all specimens used in the experiment survived more than three month after the experiment, our new method of DNA extraction is completely harmless for bivalves. The employment of this extraction method makes possible to access the genetic analysis of bivalves without injuring and killing. Since 2011, several local authorities and fisheries cooperative associations have begun the stock management via producing the releasing seeds and assessment of the genetic population structure for branding commercial species by themself. Furthermore, they also want to establish the original lineages of commercial species including bivalves by breeding. We believe our new method supports these programs and facilitates the restoration of fisheries in Tohoku region.

【Conclusion】

1. Bivalve DNA could be extracted from the water filling mantle cavity without injuring and/or killing.
2. 5-min drying treatment was enough to extract DNA for PCR amplification. There was no contamination of the DNA from other organisms in this study.
3. All specimens used in this experiment survived more than three month after the experiment.

【How we investigated】

All specimens were separately placed in the water tank filling the filtered seawater before experiments for 24-hour. The specimens were placed on the dish without water for the drying treatment to accumulate the body waste containing DNA for 5-min, 15-min and 60-min, respectively. Then 0.5-2ml MCW was extracted by 5ml syringes with 23G needles. DNA extraction from MCW was conducted by ZR Urine DNA Isolation Kit (Zymo Research). Each primer sequence is described as bellow;

CO1F: GGTCAACAAATCATAAAGATATTGG
CO1R: TAAACTTCAGGGTGACCAAAAAATCA
H3F: ATGGCTCGTACCAAGCAGACVGC
H3R: ATATCCTTRGGCATRATRGTGAC
LSUF: TAGGTCGACCCGCTGAAYTTAAGCA
LSUR: AGCGCCATCCATTTTCAGG

DNA was sequenced using an outsourced service (Fasmac).

Development of new short-term aquaculture system

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Key words: aquaculture, barren, cage culture, gonad quality, sea urchin

【Background】

Mesocentrotus nudus is a common sea urchin in northern Japan and is harvested commercially. This species inhabits barrens in subtidal rocky bottoms in high density. However, the gonads (roe) from barrens are smaller and less yellowish than those from kelp beds, result in low market value. In Japan, the roe has been enhanced by transplanting adult *M. nudus* from barrens or deep waters to kelp or fucoid beds. Although a few feeding trials indicated enhancement of the gonad production and improvement of the gonad color of *M. nudus* on barrens, improvement of overall gonad quality is not still evaluated.

【Aim】

Present study aims to improve low gonad quality of *M. nudus* on barren by the short-term cage culture.

【What we found】

The gonad index of cultured sea urchins increased from 6.3 to 15.6, significantly higher than that from the barren. The value of ΔE_{ab}* in the gonad of cultured urchins was lower than that from the barren, indicating improvement of total gonad color (Figure 1). Coefficients of variations of gonad indices

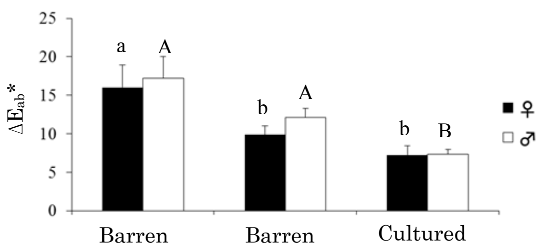

Fig. 1. Values of ΔE_{ab}* in the gonad of *M. nudus* from barren and cage culture

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and gonad color (L*a*b*) between individuals reduced from the start to the end of culture (Fig. 2).

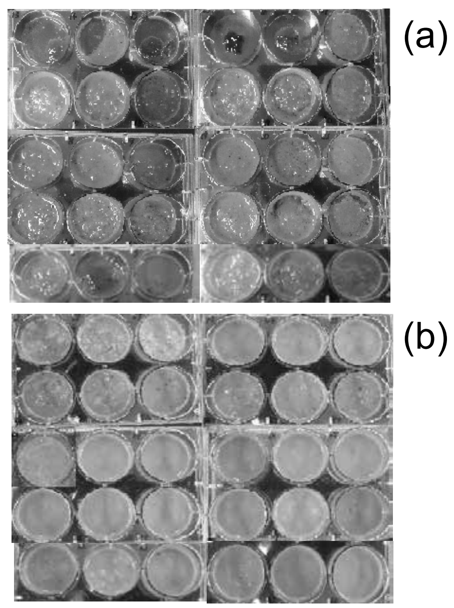

Fig. 2. Individual gonads of *M. nudus* at the start (a) and the end of culture (b).

The gonad firmness of the cultured urchins was closer to that from the *E. bicyclis* kelp bed.

The sweet-tasting amino acids, alanine and serine in the gonads of cultured urchins increased. In contrast, the bitter-tasting amino acids, arginine and lysine decreased significantly. The gonad of the urchins from cage culture and the *E. bicyclis* bed was evaluated highly by the persons involved fisheries.

We presume that extension of feeding duration would increase gonad size and further improve gonad quality.

【Conclusion】

- Overall,short-term cage culture of *M. nudus* fed *Saccharina japonica* improved gonad color, firmness and flavor, in addition, taste and the associated free amino acid contents in the gonad.
- Cage culture reduced variations of gonad size and quality between individuals.

【How we investigated】

Sea urchins were collected from a barren and were cultured in a cage suspended from rope for 3 months from February to June 2014 in Shizugawa Bay, Miyagi Prefecture. Sea urchins were fed on the stipes inside of sporophylls of the kelp *Undaria pinnatifida* for the first 2 months, then, the kelp *Saccharina japonica ad libitum* every 7−10 days until the end of culture.

For 30 specimen harvested from the cage and 30 specimen from each of the barren and *Eisenia bicyclis* kelp bed at the start and the end of the culture, their test diameter, body weight and gonad weight were measured. The gonad index (gonad weight×100/weight) was calculated. The gonad color (C.I.E.L*a*b*) and gonad firmness were also examined. Using the values of gonad color, we calculated total color difference (ΔE_{ab}*).

The content of free amino acids in each gonad was analyzed. Sensory evaluation of the gonads was carried out by persons involved fishery in Sizugawa Bay.

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Geo-environment change caused by the 3.11-tsunami disaster around the coastal area revealed by the marine geological investigation

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Key words: marine geology, geo-environment

【Background】

On March 11, 2011, the Tohoku district area along the Pacific coast suffered great damage by the recent 2011 Tohoku earthquake. In the rias bay area, a huge tsunami was generated by narrowing of the gulf size. This huge tsunami destroyed a town and laid a large quantity of debris. These debris filled up the gulf, and the muddy seawater did not clear for several months. Large scale of seabed debris flow occurred in all of the coastal area, and the geo-environment of the sea-bottom has greatly changed. Therefore we investigate to elucidate these geo- environmental changes using the marine geological approach.

【How we investigated】

We carried out a marine geological investigation (Fig-1) in the rias bay area around the Iwate pref. (Fig-2) where the tsunami damage occurred. First, we performed a seafloor topography investigation by MNB and made a basic information map. We also performed SSS investigation to obtain distribution information of the debris and to get the bottom surface sediment information. SBP investigation by high-resolution stratum exploration has carried out to obtain the vertical information of sediment and debris distribution information. These sound exploration provide the wide range sea-bottom environmental information. Seafloor observation by ROV and sub-

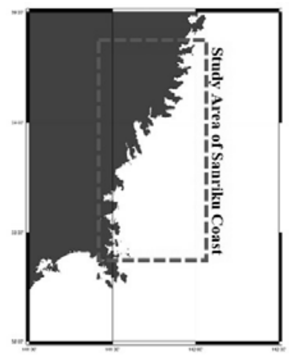
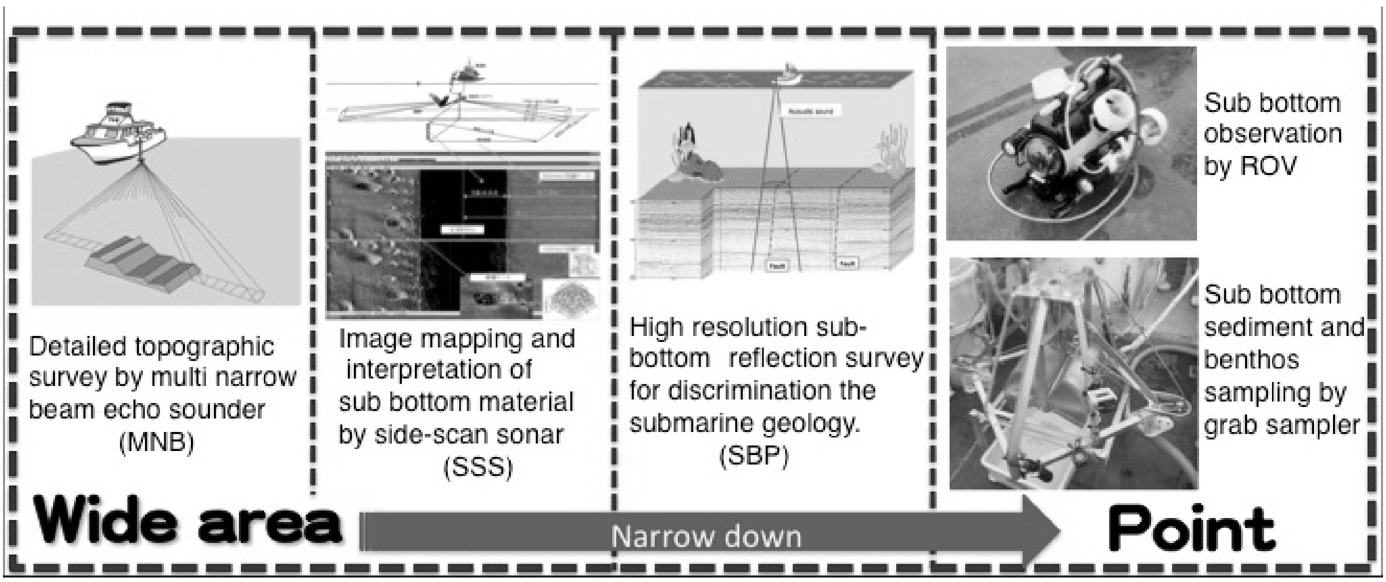


Fig.2 Study area



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bottom sampling by grab-sampler also performed to obtain the geo-environmental information.

【What we found】

1) Debris distribution and sub-bottom environment: It was confirmed that much debris artifacts (such as wood, cars, boat, net, concrete block, toys, bundle of letters, etc.) were distributed over the bottom of the sea (Fig-3). Debris more than 2000 was discovered by the SSS investigation of 2013 in the sea-bottom of -5 to -20m in depth of Hirota bay (Fig-3).

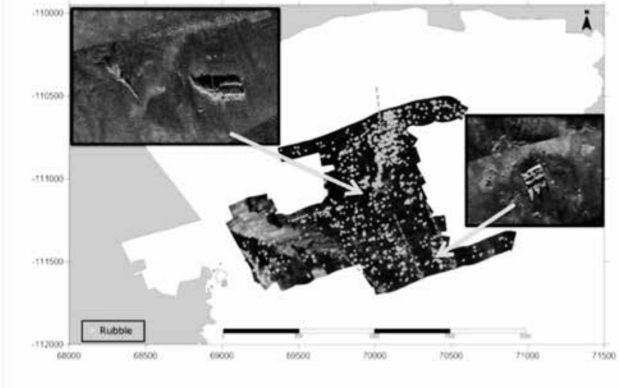

Fig.3 Debris distribution in Hirota bay.

Similar debris confirmed in the Thoni, Okirai, Ofunato, Otsuchi, and Onagawa bay. Debris removal work advances in many gulfs, but the artifacts such as cars are still discovered.

By the image mapping survey by SSS, a sediment distribution (such as silt, sand and gravel) is possible. In the Fig-4, a wide-long dune that composed sand and gravel, which characterized by strong reflector, distributed off the Kesen River. The dune space with

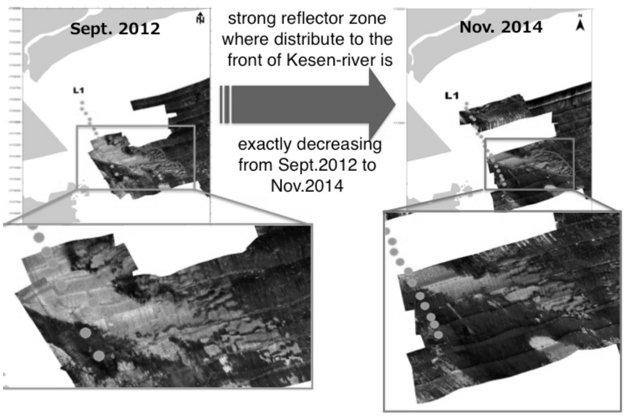

Fig.4 Huge dune with strong reflector locate off Kesen River

strong reflector in the front of Kesen River decreases over 2012 to 2014 (Fig-4). The sediment supply environment in the Hitota bay changed by this phenomenon, and it was revealed that the bottom surface became muddy environment more. The sources of mud supply in the subsurface are estimated to be by purification of nature or human activates. It is necessary to observe the secular variation of geo-environment change until it is stable.

2) The features of tsunami origin sediment:

It was revealed that the bottom sediment changed after 3.11-tsunami activity in many coast. In all of shallow (0-60m in depth) sub-bottom area except Onagawa bay, coarse sand-sediment covered the mud sediment sub-bottom floor exhaustively.

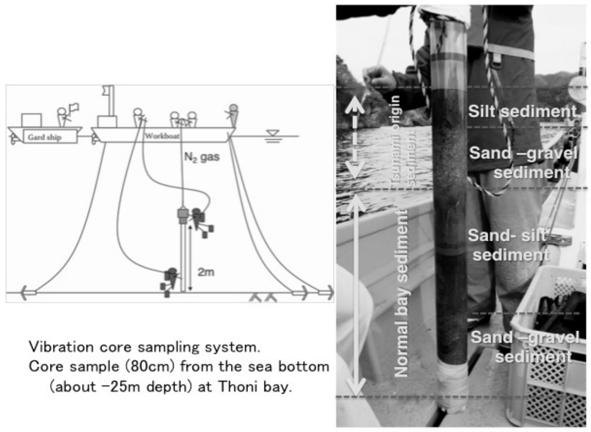

Fig.5 Vibration core sampling and core sample from Tohni Bay

Seismic survey and the vibration core sampling were carried out to examine thickness of the outer layer sediment (Fig-5). It was revealed that tsunami

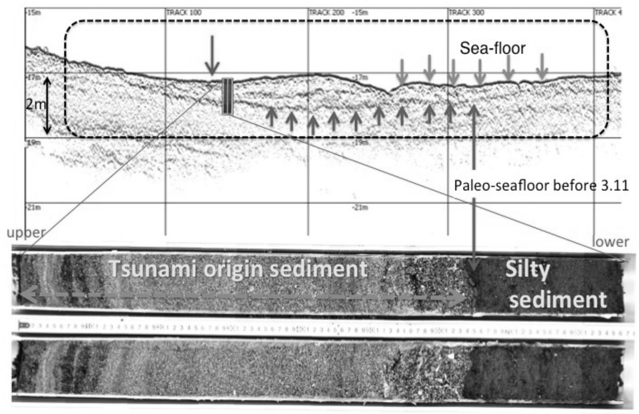

Fig.6 Comparison with the core sample and seismic result

origin sediment was distributed over the sub-bottom surface for approximately 10 to100cm (Fig-6). The lower silt layer with bioturbation is estimated as normal bay sediment. Some core samples from this silt layer include sand layer that estimated as paleo tsunami origin sediment. It was revealed that sandy sediment formed at the time of 3.11-tsunami activity was distributed widely in the coast side of the gulf. These surface sediment from coast side is gradually returning to an original state afterwards, and the growth of the creatures such as shellfishes has been observed.

What happened to the marine environments after Great East Japan Earthquake ?
TEAMS International Conference, March 2016

Characteristics of Tsunami origin sediment left by 2011 Tohoku earthquake in Hirota bay

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Key words: Tsunami origin sediment, Sub bottom profiler, Vibration core sample

Fig.1 Study area and epicenter

【Background】

The recent 2011 Tohoku earthquake affected Tohoku area, and coastal area of Pacific coast were strongly damaged by Tsunami. The study of onshore to know Tsunami effect was well researched, but offshore (especially subaqueous coastal area) was only a few researches. Tsunami were changed not only land but also ocean environment. Thus, we investigated that Tsunami effected to subaqueous coastal area from a standpoint of sediments.

【How we investigated】

From 2012 June to 2015 October, we had 11 times survey in Hirota bay. We investigated marine geological survey using Vibration core sampler (VCS) and Sub bottom profiler (SBP) in this study.

Columnar core samples carried back to laboratory and splited vertically. We wrote sedimentary structure (visual core description and soft x-ray analysis) after split, and measurement of grain size using by laser grain size analyzer (Mastersizer 3000, Malvern Instruments).

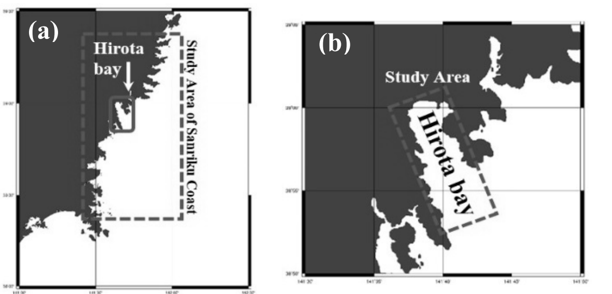

Fig.2 Study area of Sanriku coast (a: overview, b: Hirota

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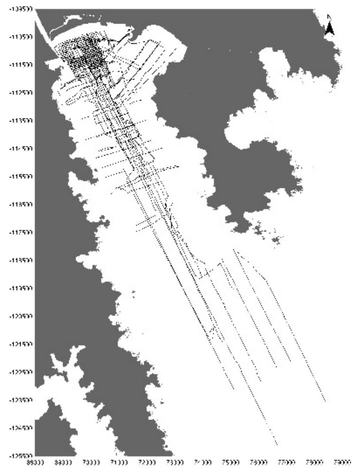

Fig.3 SBP survey lines

Especially, SBP investigated lines interval about 50m at shallow area, and about 200–500 m at the other area (Fig.3). Total survay line number were 223 and mileage was about 300 km.

【What we found】

Sediment core were corrected at water depth 8–32 m. Each core samples length were 45–195 cm.

Every core samples were able to sectionalize to mainly two lithological units (Unit1 and Unit2 from the top, Fig.4). Unit1 is sand layer at top of the core, Unit2 is mud layer at under the Unit1, sharp and very clear boundary exist in between two units.

Unit1 thickness were 7–68 cm and characterized by sand layer, normal-grading, parallel lamina, and it formed erosion structure to Unit2 (some samples contain the rip-up clast, Fig.5). This feature is similar to characteristics of Tsunami deposit on land (Naruse et al., 2012).

Grain size of Unit1 were composed of very fine sand to very coarse sand and some sample have gravel (Max size 5 cm x 5 cm) at bottom. Tsunami origin sediment at subaqueous coastal area have very wide grain size range. Therefore, we estimated Unit1 have originated as 2011 Tohoku earthquake Tsunami. And, Unit1 were Tsunami deposit in

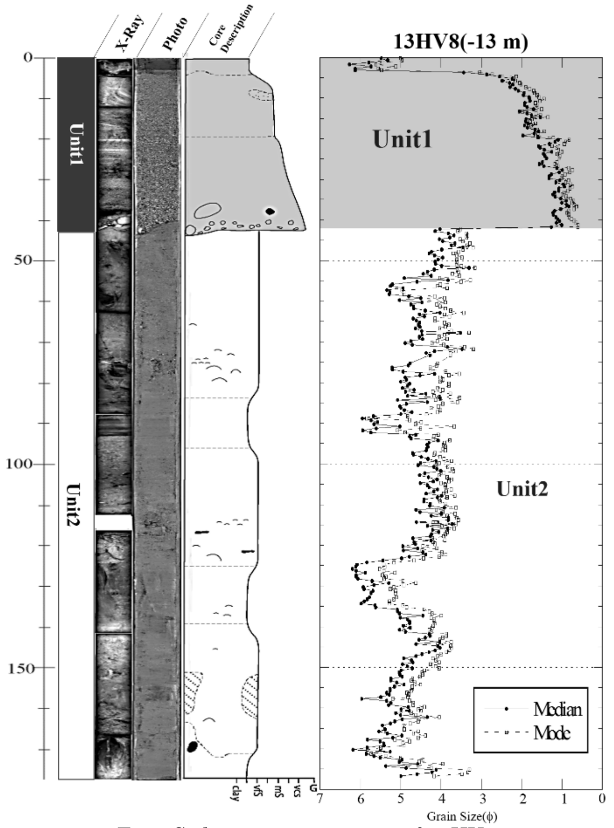

Fig.4 Sedimentary structure of 13HV8
(visual description, X-ray photo, photo and grainsize)

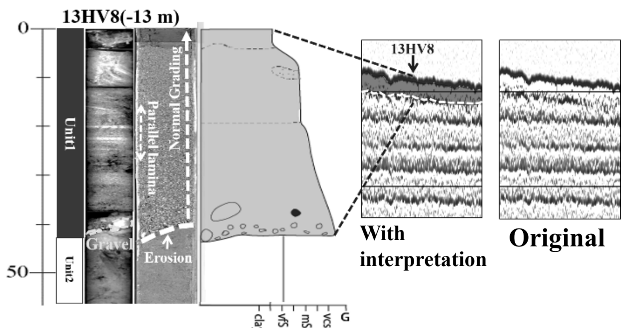

Fig.5 Detail of Unit1, correlated R1 and Unit1

subaqueous coastal area. So, subaqueous coastal area recorded about Tsunami impact as sediment like a land.

By contrast, Unit2 were characterized by mud layer and bioturbation texture. Thus, Unit2 were normal sediment (= before 2011 Tohoku earthquake sediment) in this bay. However, Unit2 contain the thin sand layer in some samples, it have possibility of paleo event sediments.

SBP data was seen a number of parallel reflection surface, and signature reflection surface on the top of them (Fig.6). That signature reflection surface (called R1) characterized by irregularity structure and clearly different from lower reflection surface. R1 was able to estimate to approximately 40 m in water depth.

R1 correlated with bottom of Unit1 at core sample (Fig.5). Therefore, R1 shown bottom line of Tsunami origin sediment. Thus our high resolution sub bottom profiler can estimated Tsunami origin sediment in this study.

The Tsunami origin sediment have a maximum thickness of about 70 cm around 23 m in water depth. These deposits thins offshore side from this area. Accordingly, we estimated volume of Tsunami origin sediment were 6.8 x 10^5 m^3 at survey area. This result was correlation with Tsunami deposit at Rikuzentakata plain (6.1 x 10^5 m^3, Naruse et al.,2012). Kato et al.(2012) reported amount of denudation at coastal land and ocean area were 1.8 x 10^6 m^3. This volume was consist almost sum total of Rikuzentakata plain and this study's Tsunami origin sediment volume.

【Further readings and information】

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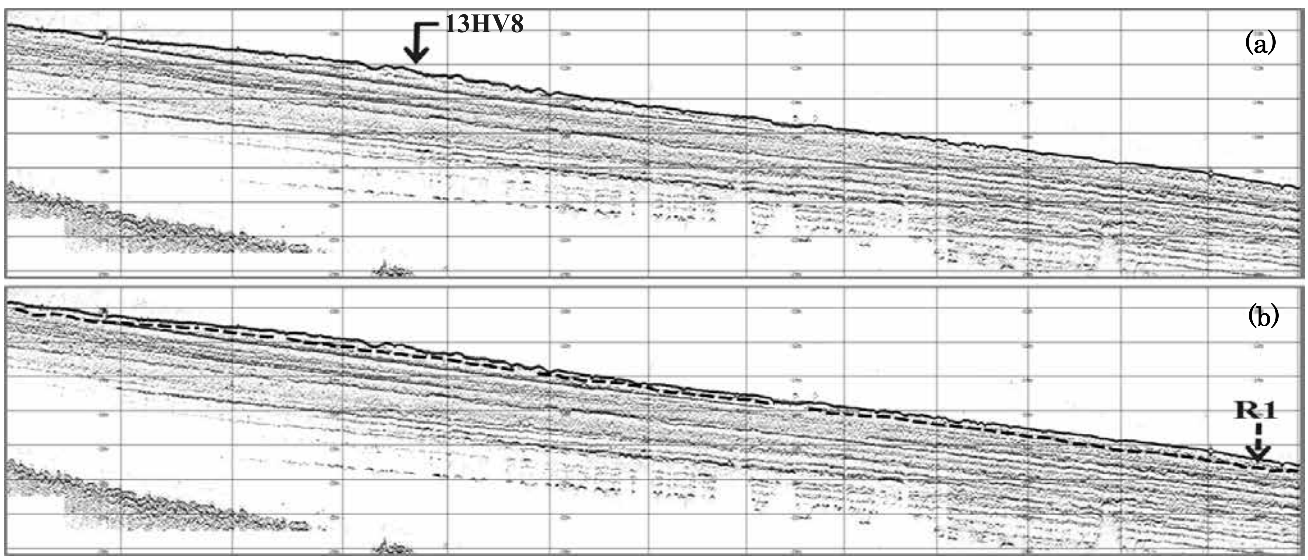

Fig.6 Sub bottom profiler data (a: original data, b: with interpretation)

What happened to the marine environments after Great East Japan Earthquake?
TEAMS International Conference, March 2016

Changes of submarine topography effect caused by 3.11 earthquakes at Toni bay

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Key words: irregularity surface, current mark, Toni bay

【Background】

The recent 2011 Tohoku Tsunami strongly affected the Pacific coastal area of Japan.

Toni bay located at southeastern part of the Iwate prefecture, extending eastward. The 3.11 Tsunami reached limit of artificial breakwater-walls (height of 12m), and drifted away numerous artificial-materials (cars, houses, ships…etc.).

So, we started survey to clarify the impact of 3.11 Tsunami disasters at Toni bay from 2012.

We carried out submarine topography survey using Multi Beam Echo Sounder (MBES) to make bathymetry map of after 3.11 Tsunami impact.

As a result, we observed topographical irregularity of seafloor features in depth 20–25m.

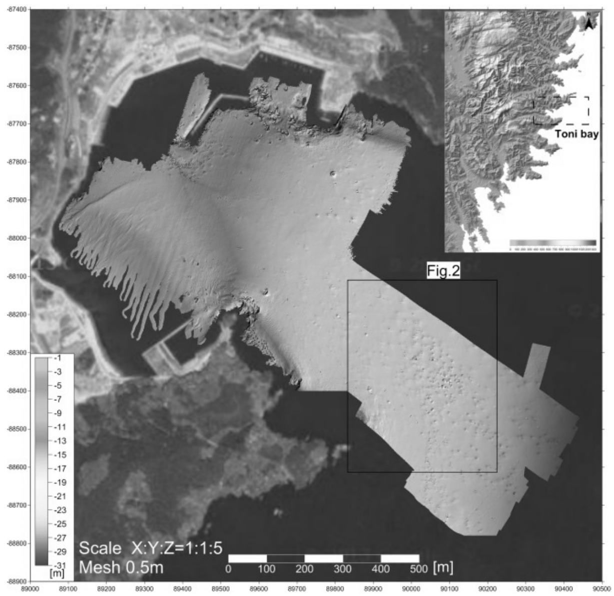

Fig.1 Bathymetry map of Toni bay

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【Aim】

To clarify the topographical irregularity features of seafloor (especially in depth 20–25m) at Toni bay based on additional survey in 2013.

【How we investigated】

We have carried out high-resolution acoustic survey using MBES. We used narrower (90 degree) swath beams in 2013. Thus our survey has 20 centimeter accuracy (Fig.2).

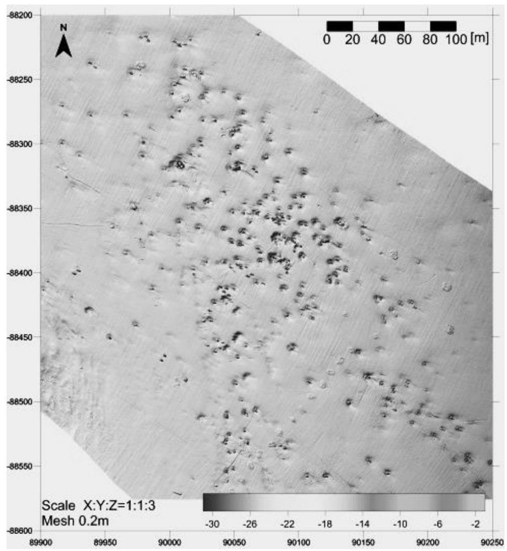

Fig.2 Irregularity surface area

【What we found】

We observed over 300 marine debris and current marks formed around them. We divided the current marks into two types (Multidirectional type and Unidirectional type; Fig.3).

1) Multi-directional type: This type is circle-shaped. Those are almost formed around marine debris (Fig.3a), but some of them formed without marine debris (Fig.3b). These are distributed with density on depth 20–25m (Fig.4).

2) Unidirectional type: This type is spindle-shaped or comet-shaped, open like a fan toward offshore and almost them elongate NW-SE direction. These are widely distributed in survey area. In the cross section along NW-SE direction, these are formed asymmetric shape such as upstream side steeper than downstream side (Fig.3c). We count the elongate directions of over 300 current marks. As a result of mode values is N47W-N52W (Fig.5).

The results suggest that these current marks formed by strong water flow with NW to SE direction same as axial of Toni bay.

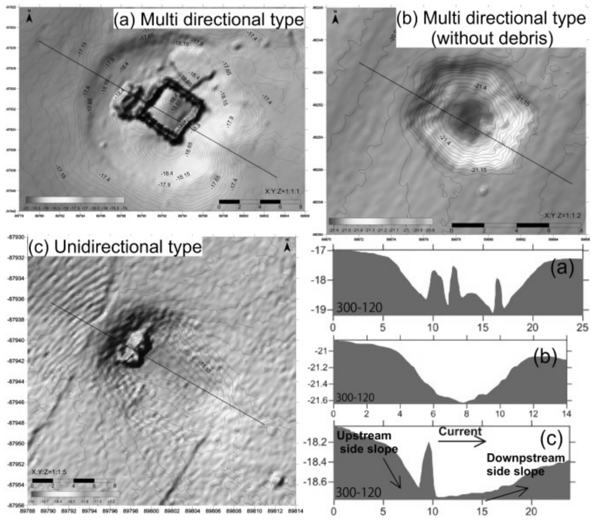

Fig.3 Type of Current marks and sections

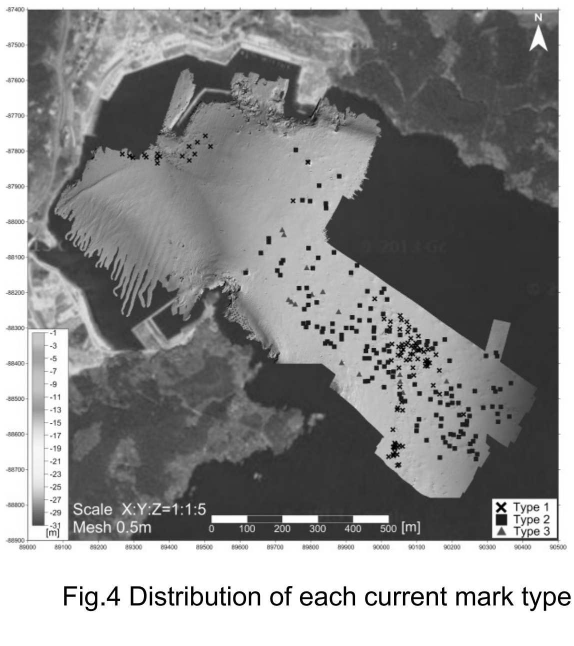

Fig.4 Distribution of each current mark type

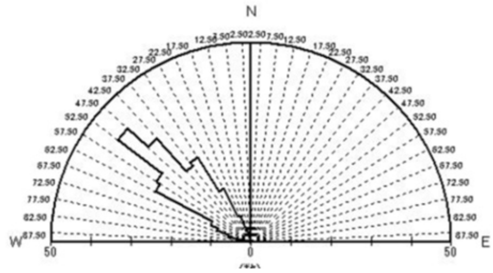

Fig.5 Rose diagram of elongation direction of current marks

On the other hand, there is no current mark around the rafts-weight, which put on after 3.11 Tsunami activities (Fig.6; broken line circle). It suggests normal tidal current cannot form current mark around rafts-weight.

So, the current marks formed by huge backwash of 3.11 Tsunami activities.

Fig.6 Weight for rafts

【Conclusion】

As a result of scrutinize at irregularity topographical features area, the results shown below.

1) We observed over 300 marine debris in Toni bay. And current marks formed around them.

2) We divided the current mark into two types such as Unidirectional type and multidirectional type. Unidirectional type is most commonly.

3) In the cross section of Unidirectional type along NW-SE, upstream side formed steep angle slope, gentle slope is formed around the downstream side. It is suggests water flow with NW to SE direction.

4) There is no current mark around the rafts-weight, which put on after 3.11 Tsunami activities.

From the above, a lot of debris drifts away by Tsunami, and debris fall to the seafloor. After that current mark formed by backwash of Tsunami. So, 3.11 Tsunami affected submarine topography at Toni bay.

【Further readings and information】

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Recovery of the benthic ecosystem

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Key words: Tohoku offshore areas, deep sea, benthos, tsunami debris

【Background】

On March 11, 2011, marine ecosystems and environments of coastal areas of Tohoku district were heavily damaged by the mega earthquake and subsequent tsunamis. In offshore areas as well as coastal regions, benthic organisms and environments were supposed to be significantly suffered from turbidity current and sediment disturbance caused by the earthquake. In addition, huge amount of debris that were swept into the sea, sank to the bottom and have disturbed offshore trawl fisheries. Therefore it was important and necessary to survey actual conditions of the benthic ecosystems and the sunken debris accurately at the offshore fishing grounds of Tohoku.

【Aim】

Aims of this research project were 1) to monitor restoration process of the benthic ecosystems of offshore areas of Tohoku after the mega earthquake, 2) to investigate the distribution and quantity of the sunken tsunami debris, and 3) to elucidate impacts of the huge earthquake and tsunami debris on the deep-sea benthic organisms. Information from these results has been provided to the fisheries and the local government agency as needed, in order to contribute revitalization of fisheries in Tohoku offshore areas.

【What we found】

1. A large number and high diversity of the benthic animals including fisheries resources have been found on the deep-sea floor at the depth shallower than 1000 meters of offshore areas of Tohoku since 2013, when first Remotely Operated Vehicle (ROV) CRAMBON survey was conducted at these areas.

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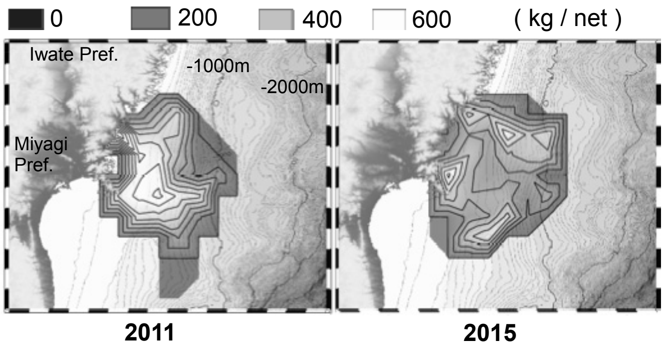

Figure 1. Distribution and density of recovered debris by trawl fishing net off Tohoku.

2. The local maps describing distribution and density of the sunken debris were made using recovered debris data from 2011 to 2015 by the offshore trawl fisheries in Miyagi prefecture. Average density of debris caught in a single trawl net has tended to decrease from year to year (Fig.1).

3. Sunken debris could rarely be find on the gentle slopes of sea floor, but accumulated on bottom of particular steep sea canyons.

4. Numerous number of benthic species such as echinoderms, crustaceans and demersal fishes, aggregated on the various debris (Fig.2, 3). The number of swarmed animals seemed to increase along with decomposition of the wooden debris.

Figure 2. Dense aggregation of benthos around deep-sea debris.

【Conclusion】

Observations using ROVs since 2013 revealed that high diversity and amount of the benthic organisms including fisheries objectives have been

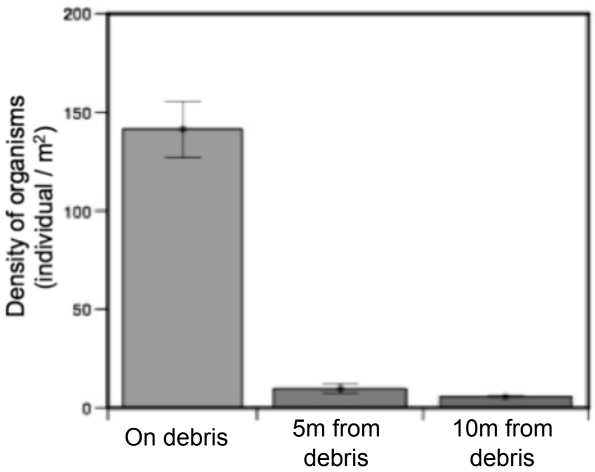

Figure 3. Density of benthos on debris and on floor far from debris.

kept around the bottom of offshore areas of Tohoku (< 1000m depth), although biodiversity and biomass before the earthquake were not comparable because detail data were defective.

Although the amounts of recovered debris have steadily decreased every year, many of debris were supposed to remain on the bottom of deep-sea canyons that have never observed. To date negative and harmful effects of the sunken debris on deep-sea benthic organisms and surrounding environments have never detected. Instead, those debris have provided new habitats for deep-sea organisms.

【How we investigated】

Detailed observations about deep-sea benthic organisms and sunken debris were conducted using mainly two ROVs, CRAMBON and Hyper Dolphin. CRAMBON was specially made for investigating impacts of Great East Japan Earthquake. Number and density of benthic organisms were counted from camera images of ROVs and a deep-tow. The benthic organisms and debris were sampled using suction sampler and manipulator equipped in ROVs.

For creating debris maps, density of the debris swept off Tohoku areas were calculated using the amount of debris recovered by offshore trawl fisheries in Miyagi prefecture. Distribution maps were created using QGIS software.

【Further readings and information】

ROV CRAMBON Please visit the web site for details;
http://www.jamstec.go.jp/teams/e/kichiji/equipment.html

Research information and data are accessible at the followings;
http://www.jamstec.go.jp/teams/e/data.html

Changes in abundance and composition of anthropogenic marine debris on the continental slope off the Pacific coast of northern Japan, after the March 2011 Tohoku earthquake

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Key words: Marine debris, Tsunami, Density, sea-based source, land-based source

【Background】

Marine debris, washed ashore on beaches, floating in the world's oceans or accumulating on the seafloor, has been recognized as one of the serious marine pollutions for marine ecosystem. The Tohoku earthquake hit northeastern Japan on March 11, 2011. It triggered a massive tsunami inundated an area of about 561 km^2 and swept away estimated five million tonnes of debris, including wood, sediment, plastics, industrial materials and various structural components. Most of the debris sank to the seabed off the coast in the immediate aftermath of the disaster. The remnant were drifted far from the coast and gradually sunk and accumulated on the seafloor of the continental slope. Although such debris might negatively affect not only benthic marine ecosystems but also fishing operations, the distribution and volume are poorly known.

【Aim】

The goal of this study was to evaluate temporal changes in seafloor marine debris on the continental slope used as bottom trawl fishing grounds close to the areas most impacted by the tsunami.

【What we found】

During the pre-earthquake period, relatively low density of sea-base sourced items, mainly comprising fishing gear and related items from adjacent fishing grounds on the continental shelf, was abundant.

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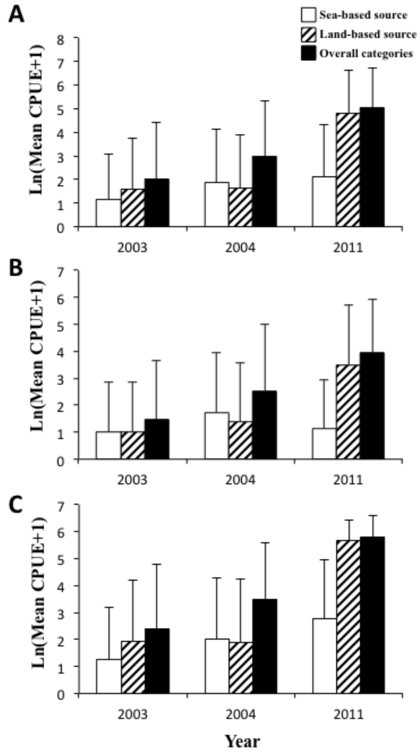

Fig. 1. Comparison of abundance of marine debris (log transformed items km^{-2}) collected from whole (A), northern (B) and southern (C) areas off Iwate by bottom trawl surveys in 2003, 2004 and 2011.

In contrast, the density increased drastically after the earthquake due to an increase of land-base sourced items generated by the tsunami and the land-based debris remained abundant from June to November 2011. It is suggested that the additional transport of seafloor debris previously accumulated on the continental shelf to the adjacent deeper slope was continued.

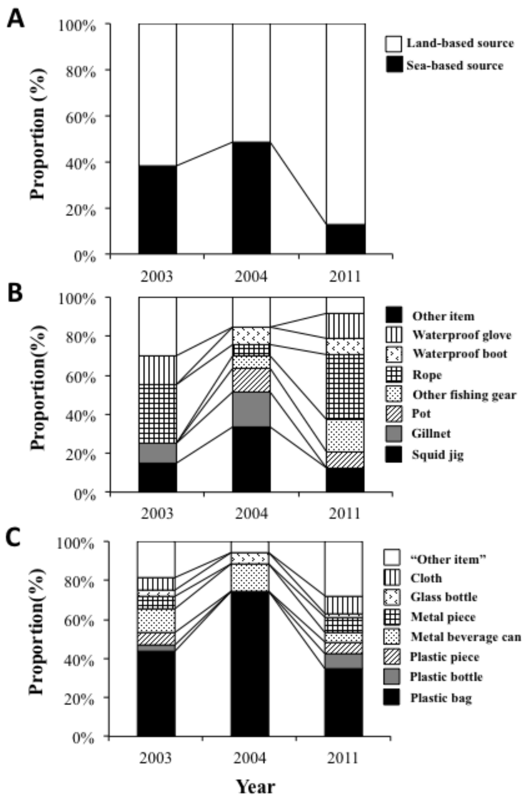

Fig. 2. Percentage composition of different categories and types of marine debris collected from bottom trawl surveys in 2003, 2004 and 2011: (A) items from sea-based and land-based sources; (B) eight sea-based source types, including fishing gear (squid jigs, gillnets, pots and "other items") and other items related to fishery or vessel activities (ropes, waterproof boots and gloves, and "other items"); (C) eight land-based source types (plastic bags, plastic bottles, plastic pieces, metal beverage cans, metal pieces, glass bottles, clothing and "other items").

【Conclusion】

1. Marine debris on continental slope off northeastern Japan quantified.
2. Low density of sea-base sourced debris abundant until 2011 Tohoku earthquake.
3. Increase in marine debris after the earthquake indicated by post-2011 tsunami survey.
4. Much increase in land-base sourced debris mainly due to 2011 tsunami.
5. Additional sources of land-based debris during post-tsunami survey implied.

【How we investigated】

Abundance and composition of anthropogenic marine debris were assessed on the basis of six bottom trawl surveys conducted on the continental slope off Iwate Prefecture, Pacific coast of northern Japan, in 2003, 2004 and 2011, and the temporal changes due to the Tohoku earthquake and tsunami in March 2011 evaluated.

【Further readings and information】

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Seasonal changes and an earthquake induced disturbance recorded by deep-sea stations in continental slope, off Otsuchi Bay, Northeastern Japan

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Key words: off Otsuchi bay, deep-sea station, monitoring, water mass, aftershock, sediment

【Background】

The 2011 off the Pacific coast of Tohoku Earthquake induced strong disturbances on the sea floor environments around the epicenter (Kawagucci et al., 2012; Noguchi et al., 2012; Ikehara, 2012; Arai et al., 2013). In plate subduction areas, the huge earthquakes have often occurred, and the sea floor might be also disturbed as documented by the studies promoted after this earthquake. However, the recovery processes at the sea floor after the earthquakes have not yet fully studied due to limitations of cruise opportunities and the method for long-term monitoring of sediment surface and the sea water.

【Aim】

The aim of this study is to investigate environmental changes on the sea floor and adjacent seawater after the earthquake throughout long-term monitoring. Development of deep-sea stations is also important mission to accomplish over 1 year-monitoring on sea water properties and taking sea floor photographs without external power supply.

【What we found】

Water mass exchange was observed at upper slope on early May 2013. Until late April 2013, salinity and temperature were high, however, both parameters were decreased during the 10th May. From the T-S plot, this change is explained by intrusion of cold water originated from Oyashio water system. On the other hand, water mass in bathyal site showed stable and typical cold lower-layer water (Hanawa and Mitsudera, 1986) (Fig. 1).

At the upper slope site, huge amount of ophiuroids were observed. Ophiuroids were also seen at the bathyal site, however, the species was different and the density was smaller than the habitats seen in the upper slope site. In early spring season, the sea floor photographs taken from the both sites recorded dense marine-snowfall (Fig.2). These remarkable events were seen after chlorophyll *a* increase observed by remote sensing (http://kuroshio.eorc.jaxa.jp/ADEOS/mod_nrt_new/index.html). The dense snow-fall events were lasted at most one or two days, and this result was supported the result from previous sediment trap study conducted off Sanriku, closer to this study sites (Saino et al. 1998).

On 7 December, 2012, heavy aftershock (M=7.3) from the huge earthquake in 2011 was occurred. This earthquake elevated the turbidity and induced the disturbance of the sea floor. The sea floor photograph at the bathyal site recorded after 6 hours and 20 minutes from the aftershock showed high turbidity and a half-burial of ophiuroids into the sediment surface. These benthic organisms, however, appeared on the sediment surface next day. The burrows were still filled with the sediment particles, and it took ca. 10 days to remove by benthic activities (Fig.3).

【Conclusions】

1. We developed two deep-sea stations and the monitoring of bottom seawater and sediment surface was carried out at the upper slope and bathyal sites.
2. Water mass exchange was observed at the upper slope site, and the short time marine snow-walls were recorded from the both sites.
3. Strong aftershock induced temporal turbidity increase and the sea floor disturbance. However, the benthic organisms were responded quickly and they appeared on the sea floor within one day from the aftershock.

【How we investigated】

We deployed two deep-sea stations and deployed two locations: upper slope (39° 19.981’N, 142° 09.994'E, initial depth of 300 m) and bathyal (39°

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19.978’N, 142° 27.519'E, water depth of 998 m) sites. The deployment periods were from 13 March 2013 to 2 September 2013 and from 14 August 2012 to 14 October 2013, respectively. The monitoring in physical and chemical water properties was measured with RDCP-600 ADCP/CTDDO turbidity sensors (Xyrem). This instrument measured intensity and direction of hydrodynamic current, hydrostatic pressure, water temperature, salinity, dissolved oxygen concentration, and turbidity in every one hour interval. The sea floor photographs were taken by handmade camera systems equipped with a commercialized HDTV video camera, LEDs and a high power lithium-ion battery in every 24 hours interval. The calibration of salinity was carried out to compare the monitoring data with salinity values obtained during *R/V* Bosei-maru BO13-20 cruise conducted off Otsuchi bay between 28 October and 10 November 2013.

【Further readings and information】

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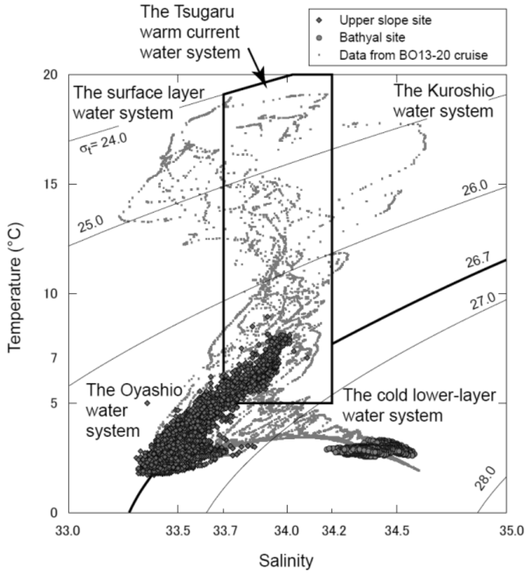

Fig 1.Temperature=Salinity plot of the data recorded by the monitoring and obtained during the BO13-20 cruise.

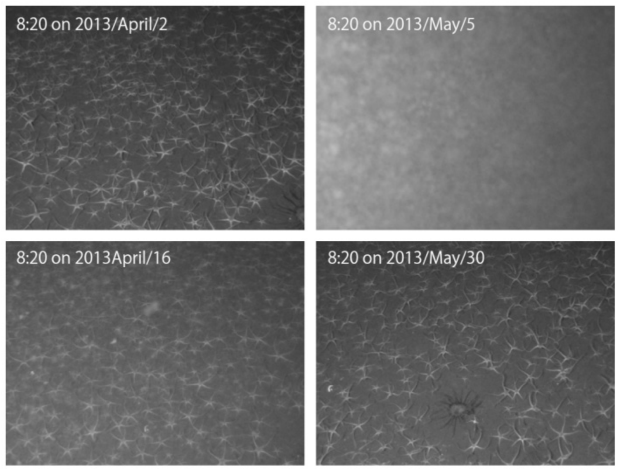

Fig 2.Time series sea floor photographs at the upper slope site. Dense distribution of ophiuroids was seen. Heavy marine snowfall was observed on 5 May 2013.

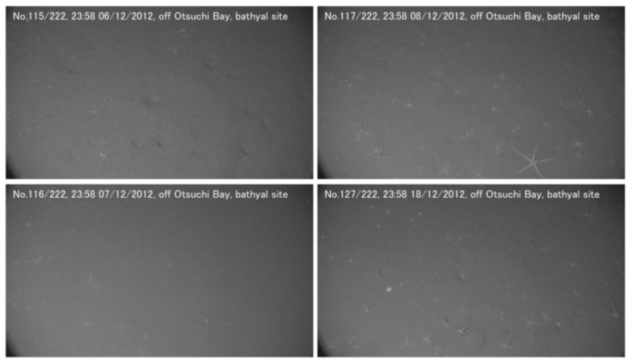

Fig 3.Time series sea floor photographs at the bathyal site. High turbidity induced by the aftershock was recorded on 7 December 2012. The ophiuroids were recovered by 8th.

Use of bottom image mapping by a new underwater camera system, and application of 3D mosaicking to observe the spatial distribution of benthic organisms off the coast of Sanriku.

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Key words: image analysis, 3d photo mosaic, deep-sea image, brittle stars

【Background】

To determine the changes in deep-sea bottom ecosystems after the Great East Japan earthquake, it is necessary to observe the distribution of organisms. The use of destructive methods such as dredging or core sampling is a common approach to sampling organisms in deep-sea research. In recent years, camera images and video movies have become more popular. This is not only driven by improvements in resolution, but also due to the necessity of obtaining information on broad-scale natural distributions spatially, which is especially needed to model species distribution and ecosystem functions, such as the density of species.

【Aim】

To determine the density and distribution of bottom organisms after the earthquake, we created a downward-facing underwater camera for the ROV Crambon. We determined the distribution of dominant species of brittle stars by manual extraction. We also conducted image mosaicking using 2-dimensional (2D) or 3D analysis methods. Using these data, we evaluated the density of other organisms that were sparsely distributed. The mosaicked images were also plotted on a 3D map. We discuss the usefulness of the visualization of the deep-sea bottom surface.

【What we found】

The density of brittle stars off the coast of Minami-sanriku, Kamaishi and Otsuchi in 2013 was 640, 455 and 87 m^{-2}, respectively. Size structure varied greatly among the three locations. In the area off the coast of Minami-sanriku, only a single cohort was observed. Three cohorts and numerous small individuals were observed off the coast of Kamaishi. At the Otsuchi site, traces of some type of dredging were observed.

What are the Brittle stars?
Brittle stars (Ophiuroidea) are a dominant benthic fauna inhabiting the upper bathyal zone off the Sanriku coast at a depth of 200–600 m. Population density and biomass of brittle stars in this region have been estimated at 373 individuals m^{-2} and 124 g m-2, respectively (Fujita and Ohta 1989). Predation on small fish and cuttlefish has been observed and feeding on settled particulate organic matter is also suspected. Brittle stars are considered one of the food resources of some fish based on their gut contents.
The three dominant brittle star species mainly observed in the muddy flat bottom off the coast of Sanriku are *Ophiura sarsii* Lütken, 1855, *Ophiura leptoctenia* HL Clark, 1911, and *Ophiophthalmus normani* (Lyman, 1879).

Based on preliminary results from other data, the density of brittle stars can vary across several km, even at the depth of the densest area. Because there are three major dominant species, the extraordinarily high number of small individuals might consist of smaller species.

Even when target points at the bottom were not well distinguished, it was possible to mosaic in 2D mosaic method in several locations where pictures had been taken in 1 second interval from 2m hight. The processing time required to compute over 100 images was almost a half of hour in the case of the 3D mosaic. If the image was linearly captured from a similar altitude, the 2D panorama is faster and more efficient. Using these images, it is possible to estimate the density of sparsely distributed species.

【Conclusion】

1. Density of brittle stars varied greatly by location, which was also suggested by their size distribution. Density may not have been affected by the tsunami

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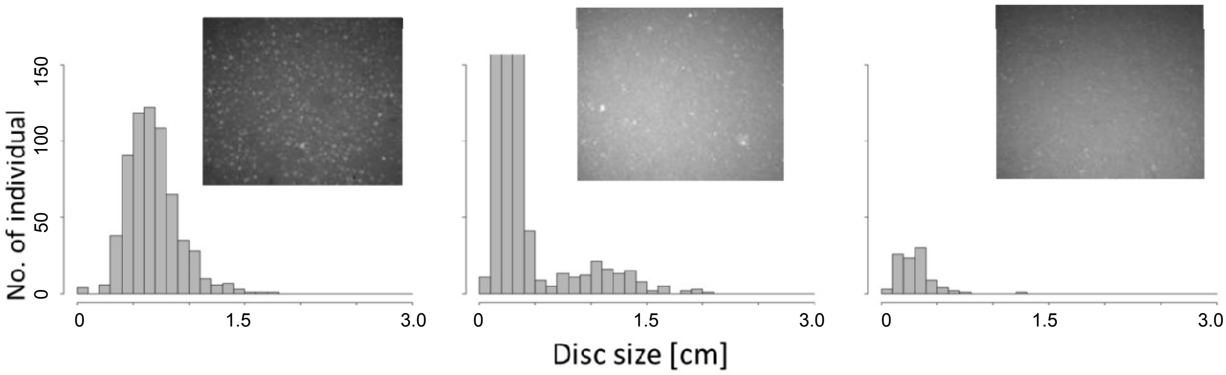

Fig. 2. Example of size structures in brittle star populations at three locations
（left to right: off Minami-sanriku, off Kamaishi and off Otsuchi）

or earthquake in this region, but rather by human activities.

2. Use of the mapping enabled us to spatially observe the bottom environment. More research of this type should be conducted to monitor sparsely distributed species.

【How we investigated】

We conducted a cruise from June 29 to July 5, 2013, using KAIYO MARU No.3, owned by Fuyo Ocean Development & Engineering Co., Ltd.

For the extraction of organism data from the images, we first traced their outlines on a touch panel display, then extracted these using the particle analysis function in a program Image J. The size of the brittle stars was corrected based on the height information of the DVL and the lens specification. The camera used had a 5-megapixel (2448x2048) resolution with a 2/3-inch sensor and an 8-mm focal distance, and ca. 43 x 28 degree visual field underwater .

【Further readings and information】

Some images are available at the followings;

http://www.i-teams.jp/catalog/rias/e/

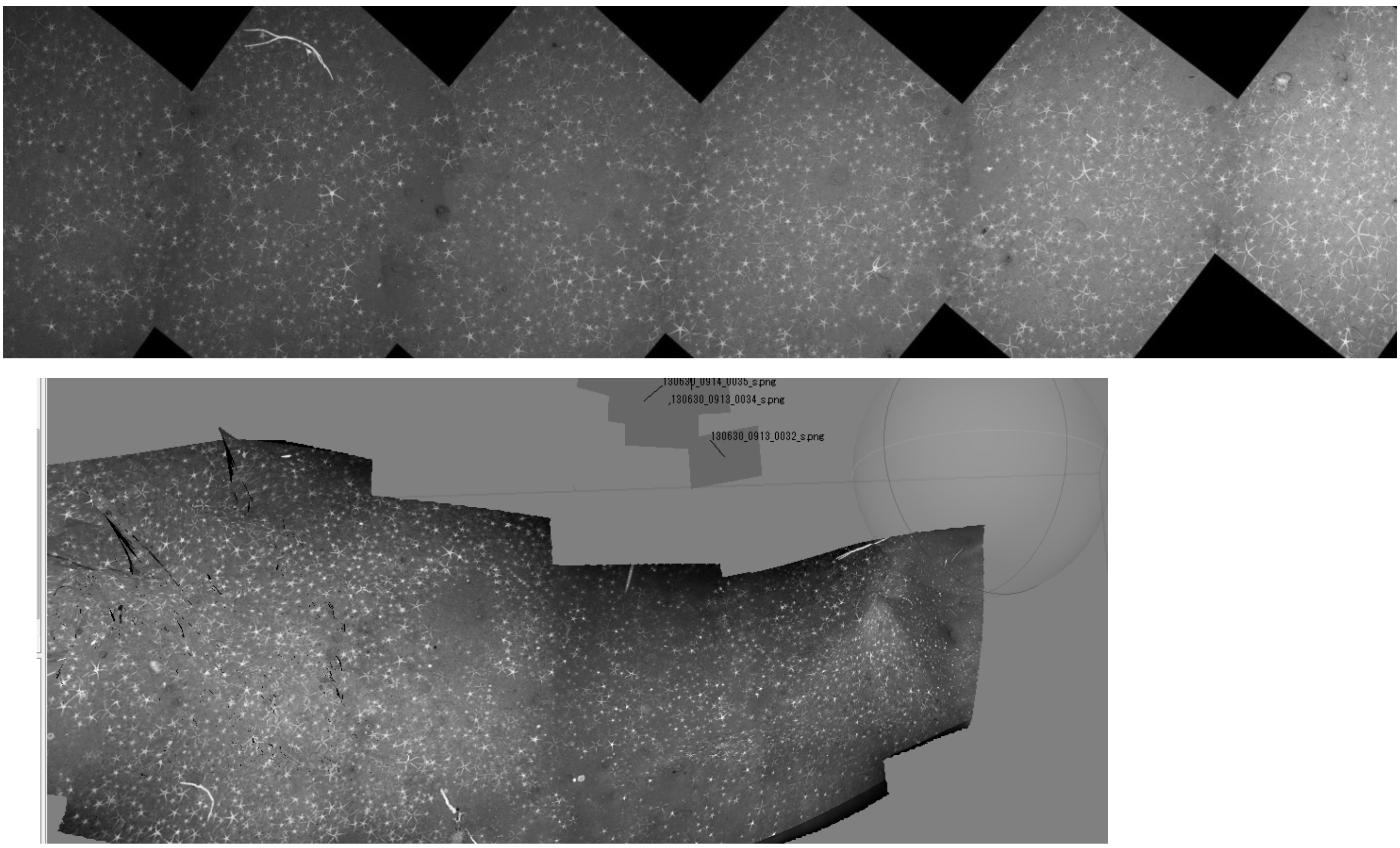

Fig. 2. Mosaicked images based on two different methods: 2 D Panorama（Upper）3D Mosaic（Lower）

Habitat mapping: potential distribution of the coastal benthic species and potential usefulness in offshore deep sea

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Key words: species distribution modellings (SDMs), benthic organisms, deep-sea, oyster, GIS

【Background】

The impact of the Great East Japan earthquake was spread over a wide area of east Japan. Collecting data on subsequent changes in marine organisms is fraught with difficulties. To predict the recovery potential of the ecosystem, it is also essential to estimate the distribution of suitable habitats for these species. In recent years, such habitat maps have been used to evaluate areas that are important for species diversity, and species distribution models enable us to perform predictions of recovery potential.

【Aim】

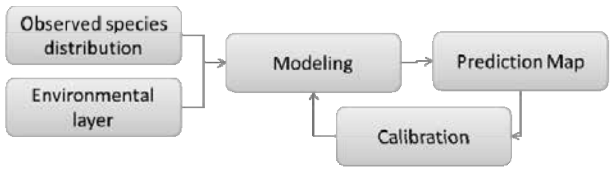
In this study, we estimated the distribution of suitable habitats using the pre-disaster distribution of benthic organisms observed in a tidal flat. Overlaying these estimates and a map of the earthquake damage enables an evaluation of earthquake impact on the organisms and of the recovery potential . Here, we summarize the preliminary results obtained at a coarse resolution, using the Pacific oyster *Crassostrea gigas* as an example.

We also show the progress made regarding the potential of similar analyses in deep-sea waters, particularly with respect to the use of previous data from literature and databases.

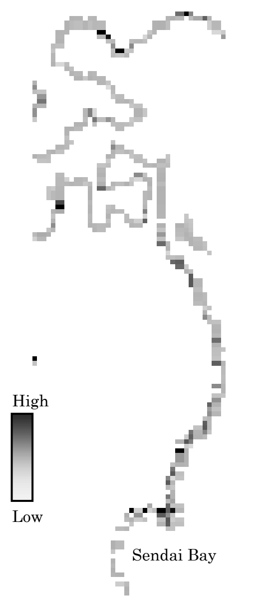
【What we found】

Based on a preliminary result that included bivalves, crustaceans and polychaetes, the distribution of tidal flat benthic organisms was affected by the shoreline length of the grid that represented the complexity of the coastline. Turbidity, which was represented by Particle Inorganic Carbon (PIC) estimated from satellite data, also showed a high average contribution.

What is the species distribution modelling?
Species distribution models (SDMs) are statistical models used to predict species occurrence or abundance using environmental variables as predictors. They are seeing increased use particularly in biodiversity conservation because they enable the evaluation of the spatial distribution of habitats across the landscape.



The natural distribution data of the Pacific oyster in a tidal flat showed a high AUC and could be sufficiently predicted using only a half of the data (AUC = 0.87±0.06). The length of the coastline contributed 34 percent and was positively related to occurrence. PIC and tidal height contributed 28 and 11 percent, respectively. In contrast, water temperature, which has featured in recent years in discussions of global warming, was not selected as



Name	Number of cells	Mean	Minimum	Maximum	SD
Kuji Bay	2	0.1	0.0	0.2	0.1
Noda Bay	4	0.2	0.0	0.4	0.2
Miyako Bay	1	0.5			
Yamada Bay	3	0.3	0.2	0.4	0.1
Funakoshi Bay	1	0.2			
Otsuchi Bay	1	0.4			
Ryoishi Bay	2	0.4	0.1	0.6	0.3
Kamaishi Bay	1	0.4			
Toni Bay	1	0.2			
Yoshihama Bay	3	0.3	0.0	0.6	0.3
Okirai Bay	1	0.5			
Ryori Bay	1	0.4			
Ofunato Bay	2	0.5	0.5	0.6	0.1
Hirota Bay	2	0.4	0.3	0.5	0.2
Kesennuma Bay	2	0.6	0.4	0.7	0.2
Koizumi Bay	2	0.3	0.1	0.5	0.2
Shizugawa Bay	4	0.4	0.2	0.5	0.2
Oppa Bay	1	0.2			
Naburi Bay	No data				
Ogatsu Bay	2	0.4	0.4	0.5	0.1
Onmae bay	No data				
Onagawa Bay	2	0.6	0.6	0.6	0.0
Samenoura Bay	1	0.6			
Sendai Bay	41	0.2	0.0	0.7	0.2
Ishinomaki Bay	12	0.4	0.0	0.7	0.2
Matsushima Bay	4	0.3	0.1	0.4	0.1

Fig. 1. Suitable habitat of oysters in 5km resolution using annual mean environment data and natural distribution at a tidal flat. Table is the extracted result in the each bay.

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an important value. This may however be due to the use of annual average sea surface temperature and biases of the samples. Selection of the appropriate season for data sourcing is one of the remaining challenges.

The potential distribution of the oyster is shown in Figure 1. Maximum potential occurrence probability exceeded 0.5 in many areas of the coastline. However, high variation was observed in each bay, likely caused by local environmental differences especially coast complexity.

A search for data that might enable similar analyses for deep-sea waters yielded some studies that were conducted off the coast of Otsuchi. In addition, geological surveys have been conducted in numerous areas along the off the coast of Sanriku.

While video data collected by JAMSTEC is available from 15 dive points along the continental shelf (Figure 2), most of the survey did not consider organisms and detailed images of the bottom are not available. Other Sanriku offshore surveys have been conducted around a trench of geological interest; however, these are not useful for predictions at the continental level because of considerable differences in depth and geography.

【Conclusion】

1. Even in areas that were strongly affected and damaged by the earthquake and tsunami, there are numerous potential habitat sites. It is important to promote the recovery of the habitat environment in such locations.
2. There is adequate data to evaluate the past situation in the deep sea. However, there is a lack of studies targeting the continental shelf, and maintaining and expanding those records is strongly suggested.

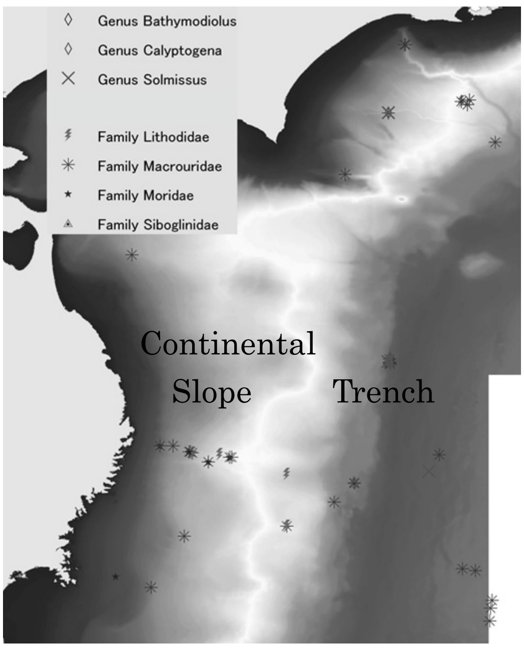

Fig. 2. Dive point which had any biological comments.

【How we investigated】

Nationwide distribution data of tidal flat organisms and seaweed/seagrass beds were used as the organism data. Environmental variables were extracted from several databases and consisted of the shape of the coastline, distance from the coast, topography, annual average sea surface chlorophyll a, water temperature and PIC, distance from the natural coast, wave height and tidal height. Most of the data were obtained from the J-IBIS, MODIS Ocean color, web, JTOPO30 and ECMWF. We predicted the distribution of each species in program MAXENT using these variables.

For the deep-sea data, we reviewed previous information from the literature and other datasets. In particular, we extracted previous video commentary information recorded onboard ship; this information was collected by JAMSTEC and was obtained from the video database JEDI.

【Further readings and information】

Yamakita, T., Yamamoto, H., Nakaoka, M., Yamano, H., Fujikura, K., Hidaka, K., et al. & Shirayama, Y. (2015). Identification of important marine areas around the Japanese Archipelago: Establishment of a protocol for evaluating a broad area using ecologically and biologically significant areas selection criteria. *Marine Policy*, 51, 136–147.

Yamakita, T., Yamamoto, H., Yokoyama, Y., Sakamoto, I., Tsuchida, S., Lindsay, D., et al. & Kitazato, H. (2015) Distribution of the Marine Debris on Seafloor from the Primary Report of Five Cruises After the Great East Japan Earthquake 2011. In: Ceccaldi, H.J. et al. (eds) "*Marine productivity: perturbations and resilience of socio-ecosystems*," Springer, pp. 101–109

The models for habitat mapping is available using BISMaL mapper. Please visit the web site for details; http://www.jamstec.go.jp/bismal/

What happened to the marine environments after Great East Japan Earthquake?
TEAMS International Conference, March 2016

Online information sharing systems are crucial tools of research collaborations

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Key words: data management, research collaboration

【Background】

Since a variety of scientists joined Tohoku Ecosystem-Associated Marine Sciences (TEAMS), the project was faced with nearly the first time research collaboration with such a big team, which mainly consists of scientists from Tohoku University, Atmosphere and Ocean Research Institute, the University of Tokyo (AORI), and Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

Therefore the data management office (DMO) stood to manage TEAMS activities. The roles of DMO is collecting, storing and sharing these scientific information in public (Fig. 1).

Since the Great East Japan Earthquake was the greatest on record in Japan, the effect of disturbances on the marine ecosystem is historically noteworthy, and should be kept on a record by present scientists with modern equipment for future studies, which have great potentiality.

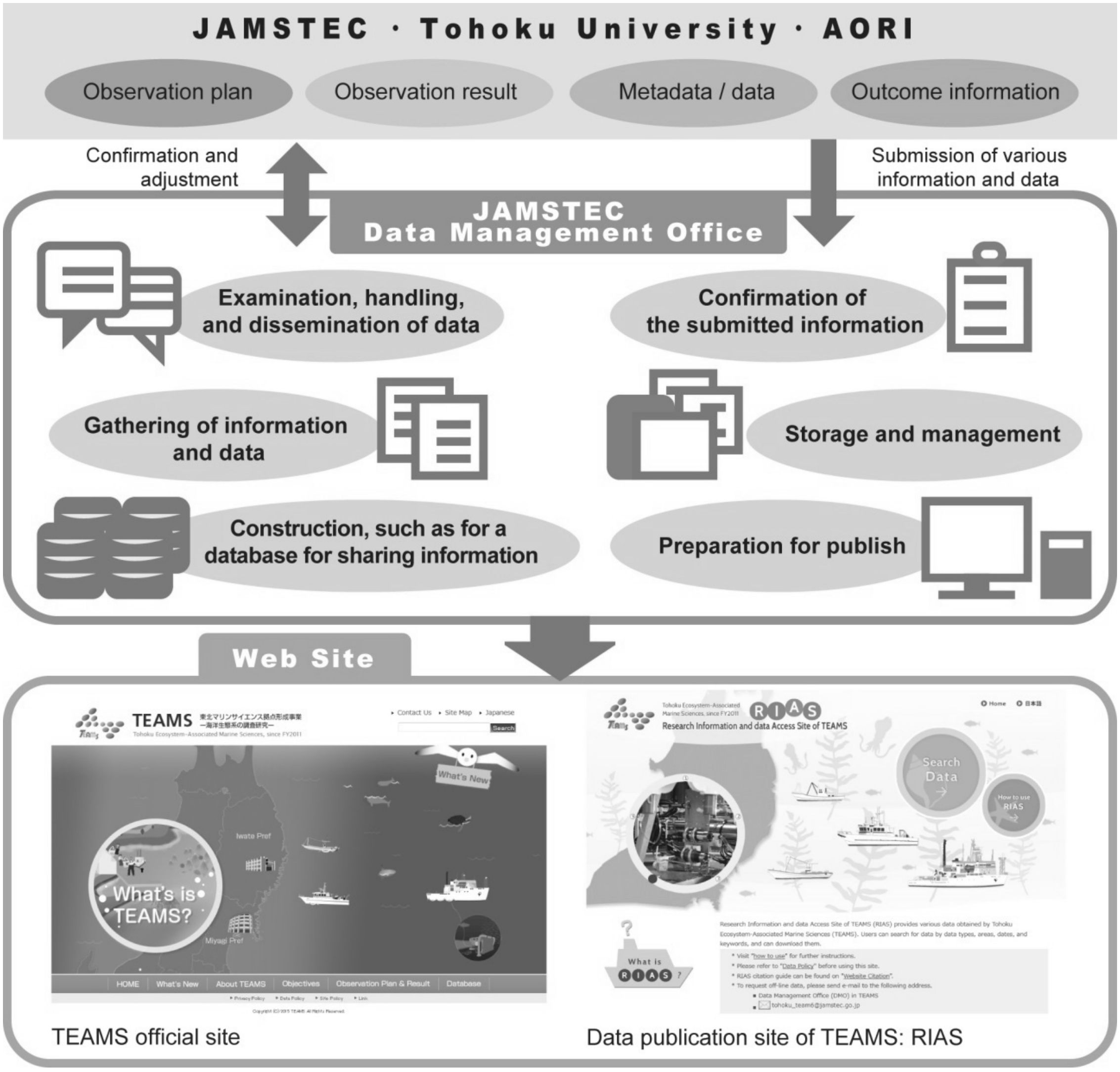

Fig.1 JAMSTEC Data Management Office (DMO) workflow

【Aim】

Our mission is collecting, preserving, and sharing the scientific information from TEAMS activities for present and future use.

To accelerate the practicality and efficiency of TEAMS activities, we constructed a private access information sharing system, which eases the difficulty to share TEAMS activities among TEAMS members.

Once we collected and archived the information, a public access information sharing system provides these for all people in the world includes Tohoku and wherever megathrust earthquake occurred such as Nepal, Chile, and Indonesia etc.

【What we found】

In the beginning, we made a Data Policy for TEAMS. The main points of the policy are followings: 1) All scientific information obtained by TEAMS activities will be collected, stored and opened to the public by DMO. 2) The property of TEAMS data and samples belong to whose institutes the scientist investigated these data and samples.

Following the Data policy and rules, we collected 145 observation plans, 84 observation results, and 163 data by December 10th 2015 respectively. The type of collected data is mainly marine physics data.

Since TEAMS have scientists from variety positions and diverse institutions, their effective collaboration is challenging although the diversity is one of the strength of TEAMS. We often heard from members that they wanted to know other members works and data but they could not. Therefore we built and provided an online private access information sharing system for TEAMS members to solve the difficulty of their collaboration. The private system is accessible to all TEAMS members and provides not only their activities and data but also news from each scientist.

In addition to the private system, we also built online public access information sharing systems. However, even though members wanted to share their activities and data, some were not ready to the public immediately but for specific people or members. In this case, we negotiated with the chairman from TEAMS' Member Institutes of the scientist who has responsible to open these scientific information to the public, and increased the accessibility of scientific information as far as possible.

As the result of that, 136 observation plans and 80 observation results were shared in an online data catalogue "TEAMS Observation Plan & Result" in TEAMS official site, and 138 data were available in an online database "Research Information and data Access Site of TEAMS (RIAS)" by December 10th 2015 respectively.

Now, we are constructing a public system to share videos recorded by TEAMS, as we did for TEAMS observation plans, observation results and data.

【Conclusion】

The success of research collaboration requires having online information sharing systems to collect information and data, and share among research members, other scientists or public in a step-by-step manner. With the collaboration of TEAMS members, although scientists need to share all of their activities and data with society, these scientific information should be carefully examined before sharing. Our systems are able to collect research information through online network and share these information with society at appropriate timing.

【How we investigated】

As a first step to develop an online information sharing system, we made Data Policy (http://www.i-teams.jp/e/data_policy.html) with the Data Management Task Group, which are representatives from each project member, as a fundamental agreement for managing the scientific information. In addition that we also made rules and formats for collecting the scientific information from research members.

After we collected and preserved the scientific information, we built an online private access information sharing system for TEAMS members which provides all activities and data from TEAMS. In the same time, after careful examinations of the scientific information with scientists, we share the publishable scientific information of TEAMS with the public through online public access information sharing systems we build. Therefore we built internet accessible information sharing systems with adjustable sharing members.

【Further readings and information】

The activities of TEAMS, which includes an online data catalogue "Observation Plan & Observation Result", can be browsed from this site; TEAMS official site http://www.i-teams.jp/e

The data collected by TEAMS members is available from this database; Research Information and data Access Site of TEAMS (RIAS) http://www.i-teams.jp/rias/e/

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TEAMS database and information publishing

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Key words: data base, information system, data publishing

【Background】

Tohoku Ecosystem-Associated Marine Sciences (TEAMS) is a research project to promote the revitalization of fishery industries through clarifying the influence of the Great East Japan Earthquake on the marine ecosystem off Tohoku area. To conduct basic and applied researches in large scale in the damaged area, close coordination with industry, government, local community and academia (investigators) is required. For close coordination, reliably managing data/information obtained through project activities and quickly sharing the data/information with related members are extremely important. To construct frameworks to realize quick data sharing within related members, speedy data providing to research institutions, and disseminating these data/information in a understandable form to local communities is one of the major challenges of this project.

【Aim】

To promote providing useful data/information in contributing to revitalization of fishery industry, we constructed integrated management system for data/information obtained in the project. In concrete, we (1) formulated TEAMS data policy as a prerequisite for data/information publishing, (2) developed database/information system for data sharing and publishing, and (3) also constructed a direct supporting system for biological research activities.

【What we found】

(1) Data policy

Prior to starting of data/information sharing and publishing, TEAMS developed ground rules in managing the data/information they collected (http://www.i-teams.jp/j/data_policy.html), and decided on the flow of operations with regard to managing data/information in TEAMS [refer to Ichiyanagi et al. (2016) in this proceeding]. It was a great achievement that data policy was decided and that data/information was published under the policy immediately after the earthquake when the idea of "Open data" was not so widely recognized in Japanese scientific society.

(2) Database/information system for sharing and publishing

To share information on research activities with related members, "TEAMS Members Site" was developed. This system provides the members with unified management of various information such as their research plans, measurement data, reports, and other products. For the convenience of members (investigators), this system has several functions such as an easily setting function to select the range of sharing (e.g., within a research party, within a task group or the whole TEAMS) and a comment function to the shared information. As another useful function of this system, members can easily recognize research activities of other parties in map view. This visibility helps to avoid setting the research plans that are similar to past/ongoing researches in TEAMS.

As regard to data/information publishing, we constructed an official TEAMS site (Fig. 1). This site can realize smooth publishing data/information which has been registered in "TEAMS Members Site". Of data/information, measurement data (e.g. sea surface temperature, wind velocity, etc.) are published in a specific system of "Research Information and Data Access Site of TEAMS (RIAS)" that was constructed for general scientists or general persons. For the convenience of users, we placed emphasis on visibility in grasping of research contents and implemented user-friendly search environments in RIAS (for example, display function in map view as shown in Fig. 2). Currently, published

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measurement data have steadily increased on RIAS (total 140 data sets related to biology, chemistry, physics, geophysics, or geology at December 7, 2015).

Fig. 1. Top page of the official TEAMS web site.

Fig. 2. Data search page of RIAS.

(3) Direct supporting system for biological research activities

To aggregate mass occurrence records of marine species obtained in ecosystem investigations in TEAMS, we also developed "Biological Observation Record Archive System (BORAS)". This system facilitates to generate a biological occurrence record in a standardized format and also facilitates to manage such records by the unit of each investigator and/or the whole team [Details are described in Iseto et al. (2016) in this proceeding]. Although biological occurrence records are important for scientific use, handling of such information requires caution from the point of view of protection of fisheries resources. Therefore, we also made a species list requiring special attention and established checking flows before publishing such records [Details are described in Yamauchi et al. (2016) in this proceeding]. We will conduct further discussion with fisheries research institutes and explore a best practice model for information publishing on fisheries species.

【Conclusion】

We have constructed "TEAMS Members Site", "official TEAMS site", RIAS, and BORAS as data/information providing environment in order to promote the revitalization of fishery industries in damaged area. Because these systems have started to work, many points for improvement will be revealed. However, a series of mechanism (datasets, information systems, data policy and rules) developed by this project shows an good model case from a point of view how scientific activities can promote supports for reconstructing damaged areas.

【How we investigated】

Although activities on data managing and publishing have been conducted by the authors, the data policy were formulated by Data Management Task Group composed of representatives of competent institutes in TEAMS. The formulated data policy was communicated to relevant members through briefings in each component institutes. Research products in TEAMS were introduced not only through our information systems, but also through workshops with local governments, relevant fishery organizations and local high schools students.

【Further readings and information】

TEAMS official site URL:
http://www.i-teams.jp/

Research Information and Data Access Site of TEAMS (RIAS) URL:
http://www.i-teams.jp/rias/

Distribution of observational data and research information using a web system

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Key words: data distribution, web system, RIAS, research activity

【Background】

Tohoku Ecosystem-Associated Marine Sciences (TEAMS) works on in the Pacific coastal and offshore areas of the Tohoku region. Observational methods in TEAMS are various because their activities cover diverse fields of science such as ecology, physics, chemistry, geology, and so on. The data and records observed by TEAMS are in wide variety of data types and format. It is important to make them available for other scientific communities.

Tohoku areas are economically important for fisheries and cultivations. Not only TEAMS but also local government and other projects conduct their researches. Therefore it is necessary to share research information among these researchers.

【Aim】

We collect, categorize, and archive the basic information of TEAMS research activities such as research plans, reports and others, and observational data obtained by researches. To promote the use and sharing of these collected information and data, we make them available to TEAMS members and also to the people in local fishery and the scientists of marine environment and ecosystem via the Internet.

【What we found】

We need information systems handling many different kinds of data and information and controlling access to these data instantly. At first, we built a web-based system to publish, search and browse TEAMS datasets on this system. We constructed three data sites; 1) Research Information and data Access Site of TEAMS (RIAS) is a data site disseminating a broad range of marine scientific data collected by TEAMS activities, 2) Observation Plan and Result of TEAMS and 3) Publication and Outreach of TEAMS (Japanese only) are web-based information catalogs in the TEAMS official website.

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Observational data are categorized by various items such as data types, methods, etc., and users can see the list of data by selecting items in the hierarchical data tree in RIAS. Furthermore RIAS has a function of searching for data by several methods. Users can also download data from metadata page selected by these approaches. (Fig.1)

Fig.1 Screenshot of the page for overviewing registered data in RIAS

TEAMS research activities are also categorized by multiple items. With these categories, these research activities can be filtered in “Observation Plan and Result of TEAMS” page. Moreover, research activities are also able to be found by text, and to be plotted the observation points on the map and to be shown the research periods by the time line chart. (Fig.2)

Fig.2 Screenshot of the page for overviewing research activities by Map and time line chart in "Observation Plan and Result of TEAMS" site

RIAS was opened to the public in the end of March 2014. In addition, a web catalog of "Observation Plan and Result of TEAMS" was also opened. After we made TEAMS observational data downloadable by RIAS, the number of data files downloaded is gradually increasing. (Fig.3)

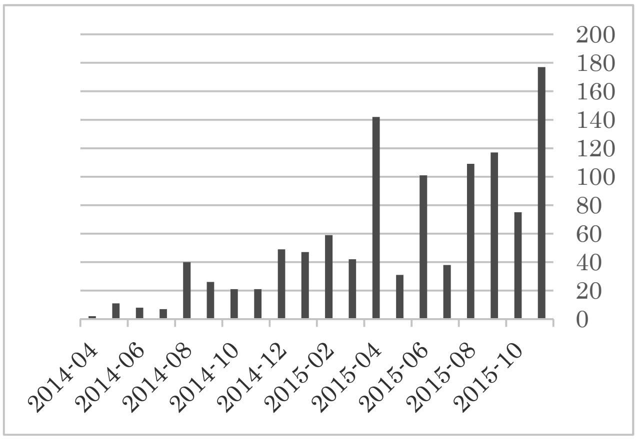

Fig.3 Changes in the number of data files downloaded from RIAS

【Conclusion】

For providing various kinds of TEAMS data and information promptly, we constructed a TEAMS dataset publication system and have released observational data and information of research activities. The system provides many ways of searching for and overviewing registered data. The site administrators can change web page design in response to types of dataset and information to make it user friendly. We have been proceeding to build out a website that releases data focusing on types of data such as videos.

【How we investigated】

We have already developed a multi-purpose data dissemination infrastructure and made it as a base of TEAMS data publication system. This multi-purpose data dissemination infrastructure is able to be applied to any metadata items and schema on the same platform. In addition, site administrators can add some items and change the schema without stopping the site on the infrastructure. Because the system automatically sorts registered data according to metadata, it is possible to search for data by a hierarchical tree, display positions by map, and show periods of records by time line chart. It is also possible to create pages of every metadata freely, to download the data file from the metadata page, and to generate external links on the metadata page. Most of features in the infrastructure system can be fully utilized for distributing various data and information of TEAMS project. Therefore, we built TEAMS data publication system using the infrastructure within a short period of time.

【Further readings and information】

Additionally, we are planning to develop a new data providing system, focused on a large amount of collected environmental data such as water temperature, salinity, etc.

The URL of the three sites

Research Information and data Access Site of Teams (RIAS):
http://www.i-teams.jp/rias/e/index.html

Observation Plan and Result of TEAMS:
http://www.i-teams.jp/catalog/plan_result/metadataList?lang=en

Publication and Outreach of TEAMS (Japanese only)
http://www.i-teams.jp/catalog/publication/metadataList

Some important scheme toward efficient use of the occurrence records of organisms and environmental data obtained by "TEAMS".

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Key words: Occurrence records, Environmental data, Darwin Core, Data format

【Background】

We have constructed several web systems to collect and disseminate information and data obtained through research activities in Tohoku Ecosystem-Associated Marine Sciences (TEAMS). These systems handle biological data acquired in marine ecosystem monitoring investigations such as a survey done by remotely operated vehicle, monitoring of fisheries resources, and studies of plankton species compositions.

In such investigations, sampling or observations for marine organisms are usually conducted. As result of this process, we could obtain occurrence records of organisms that have detailed taxonomic identifications and spatio-temporal information (event time, latitude and longitude). Occurrence records collected systematically on a large scale are critically important because these could be utilized in the analysis for understanding marine biodiversity or prediction of changes in marine ecosystem. However, a data format of these dataset often varies significantly because these data are obtained independently by each research institution and project. Therefore it is needed to be unified for wide utilization.

Further, environmental data such as water temperature, salinity and dissolved oxygen which were obtained at the time of biological investigation are necessary to be provided as available form.

On the other hand, much care is needed to open these information, such as habitat of rare species or endangered species and aquatic resource species.

【Aim】

We set up web system to make occurrence records available widely by disseminating these data in the international standard format.

Concurrently, we also deal with concern information that is related to occurrence location of organisms.

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About environmental data, we aimed to provide those various measurements data obtained by various investigations so that users may select them based on their interests.

【What we found】

We manage various data obtained in TEAMS by international standard schema "Darwin Core" thereby general versatility of data was ensured. Systems for managing, publishing and sharing the biological data also are based on the Darwin Core.

System for collection, management, sharing of occurrence records of organisms, called "Biological Observation Record Archive System / BORAS", has mounted function to retrieve information from digital photographs of organisms (such as event time, latitude and longitude) automatically that can be used to construct occurrence records of organisms in accordance to Darwin Core schema. (See paper related to "BORAS" in this proceeding)

As for the biological information which should be dealt with concern when they are disseminated, those species that are specified in endangered species in Red List and that have been nominated as fisheries resources in project area were carefully selected and the system was designed to make location information ambiguous for these species.

Furthermore, we started to develop a system which makes various environmental data, such as water temperature and salinity, available to users. The system will enable users to search those various data items by cross-sectional selection, although those data were originally acquired from independent investigations.

【Conclusion】

We have constructed a system for collecting and management of occurrence records obtained in TEAMS by using international standard format. The system handles the concerns which may arise when disseminating location information of specific species.

In addition, the development of the system is underway to disseminate the environmental data. Because organisms and their habitat environment are believed to be closely related, it is expected that the width of the data usage will be enlarged by connecting these information. We also plan to make the overlay of the biological occurrence records and the environmental data in the systems.

We hope to contribute to the recovery of fisheries of Tohoku region through promoting the use of those data obtained in TEAMS project.

【How we investigated】

To disseminate the occurrence records obtained in TEAMS as widely available data, we investigated what kind of data format is used in international biological databases. It format was validated about the applicable to the data obtained in TEAMS, and determined a standard data format in the system.

We have examined the function of the system which enables the effective use of the environmental data. Upon the consideration, opinions were collected from researchers who may actually use the environmental data.

As for the information of the species which should be dealt with concern when disseminating them, we investigated how the information of these organisms was treated in official documents and books and examined how we should follow these treatments.

What' s "Darwin Core"?

Darwin Core is a standard format adopted by international research program on biodiversity such as GBIF (Global Biodiversity Information Facility) and OBIS (Ocean Biogeographic Information System).

This format includes a glossary of terms to facilitate the sharing information about biodiversity by providing reference definitions (http://rs.tdwg.org/dwc/). Data in Darwin Core typically includes the following terms: "Scientific Name", "Longitude", "Latitude", "Event Date". It is also possible to indclude "associatedMedia" where user can describe URLs on image for each record.

【Further readings and information】

About the occurrence records of organisms.

・Global Biodiversity Information Facility (GBIF): http://www.gbif.org/

・Ocean Biogreographic Information System (OBIS): http://www.iobis.org/

・ Biological Information System for Marine Life (BISMaL): http://www.godac.jamstec.go.jp/bismal/

About "Darwin Core".

・Darwin Core: http://rs.tdwg.org/dwc/

About data obtained in TEAMS project.

・ Research Information and data Access Site of TEAMS (RIAS) http://www.i-teams.jp/rias/e/

What happened to the marine environments after Great East Japan Earthquake?
TEAMS International Conference, March 2016

TEAMS Biological Observation Record Archive System (BORAS): a web tool for managing and sharing observation data of marine organisms

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Key words: Biodiversity informatics, Database, Occurrence record

【Background】

For the monitoring of biodiversity in specific regions, collecting occurrence records of organisms are essential. Recently, those occurrence records taken by various institutions and research projects are gathering into worldwide databases such as Ocean Biogeographic Information System (OBIS) and Global Biodiversity Information Facility (GBIF). Scientists, naturalists, and even any public people observe various organisms in their daily activities and any of those observations are potentially occurrence records. However, still a lot of those occurrence records are kept personally and not contribute to the human common knowledge. Some obstacles exist for our progress; 1) making a list of occurrence records with specific data-format is complicated, 2) data are taken in many events and scattered in one's notebooks and computers, 3) people often can not identify those organisms. If we can overcome those obstacles and gather further occurrence records into the databases, we may be able to unveil much detail of biodiversity on earth.

【Aim】

Understanding biodiversity in specific localities are important for the management of local eco-systems. As a part of Tohoku Ecosystem-Associated Marine Sciences (TEAMS), we focused on the importance of understanding marine communities on Tohoku Region after the Great East Japan Earthquake on 2011 for the recovery of marine environment and for the management of the fisheries. We started to make a new web tool to gather records of marine organisms in Tohoku Region.

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【What we found】

We realized that we lack a bridge system between personal collection and open databases. We also lack a collaborative identification system. As a solution for this situation, we established a novel database system, Biological Observation Record Archive System (BORAS), which enable us to link personal data management and open databases.

Firstly, BORAS provide personal working tools to store and manage your photos and data of your observations on marine organisms. By adding three major metadata (date, location, and identification) to your observations on BORAS, most of your observations will become occurrence records.

Fig. 1. Thumbnail list of records in BORAS.

Secondly, you can share those records with other BORAS users. Any users can add identifications to the shared records. This is a collaborative work to make occurrence records. The more contributors the records have, the more appropriate for the identification.

Thirdly, you can easily publish your occurrence records through BORAS. Now we plan to add a one-click bottom to download data list with “Darwin Core” format that fit for world’s biodiversity databases. So, you will not need to combine your records into specific data format by yourself.

We also developed a mobile application for Android Operating System. Using BORAS mobile application, you can take photos of organisms and upload them directly to BORAS web system with time and location data. This may support your field activities.

【Conclusion】

We made a novel tool to overcome three major obstacles to gather further occurrence records. Once you put your photos and data into BORAS, you can expect to obtain supports on identifications by any BORAS users and on the process of data publishing. BORAS can be a bridge tool to personal activities and global databases. We plan to further improve BORAS by adding functions, especially of further user communications. We also plan to provide occurrence records from BORAS to Biological Information System for Marine Life (BISMaL), an open database that gather occurrence records of marine organisms taken by Japanese communities. Because BISMaL share its record to OBIS and OBIS started sharing its records with GBIF, the records in BORAS will acquire pathways to the world’s major databases.

Currently, BORAS is used specifically for management of TEAMS’s data by TEAMS members. Using BORAS, we expect gathering occurrence records from Tohoku Region from any research activities on marine organisms by TEAMS. BORAS will provide much detail pictures about recovering eco-systems in Tohoku Region and will help planning eco-system and fishery managements.

【How we investigated】

We developed BORAS with collaborations of biologists and system engineers. We also participated global activities on biodiversity databases to study global standards.

【Further readings and information】

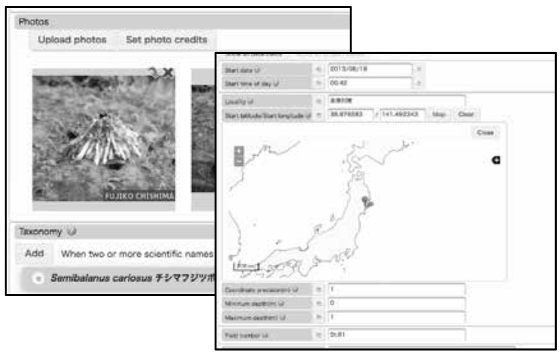
Biological Information System for Marine Life (BISMaL): http://www.godac.jamstec.go.jp/bismal/

Ocean Biogeographic Information System (OBIS): http://www.iobis.org/

Global Biodiversity Information Facility (GBIF): http://www.gbif.org/

What is the “Occurrence Record”?

Occurrence Record is a common unit of biodiversity data that consist of information of “what”, “when”, “where” an organism observed. Although scientists obtain various kinds of data through their researches, most of their data contain occurrence records of organisms. Occurrence record can be also obtained easily by public people. Recently, digital cameras and smartphones made it easier to take photos accompanied with time and location data. They are also nice occurrence records for scientific uses. “Darwin Core” is the standard data format of Occurrence Record that enable data sharing between databases.



What happened to the marine environments after Great East Japan Earthquake?
TEAMS International Conference, March 2016

Management and Publication of TEAMS Observation Videos

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Key words: video, movie, transcode, publication, management, data

【Background】

There are a lot of video data recorded in Tohoku Ecosystem-Associated Marine Sciences (TEAMS) observations. The videos are important for TEAMS researches because it is possible to identify the objects on the bottom of the sea which can not be identified by a sonar and observe marine lives behavior in detail. Moreover the videos enable researchers to observe the place such as deep sea where is difficult for humans to observe objects directly. There are many observations by using cameras attached to Remotely Operated Vehicles (ROV) and landers. In addition to that, there are videos which are recorded by cameras attached to animals such as a sea turtle and a sea bird are used for research on feeding of those animals. The videos are useful for not only investigators but also other researchers and public for secondary use. For example, another researcher use the video for the study and show the video in a school for education.

Our team have collected and published data obtained in TEAMS observations. We have to manage and publish the videos.

【Aim】

Our purpose is making use of the videos recorded in TEAMS observation for studies and understanding the sea around Tohoku area on pacific side by managing and publishing those videos. So we have to consider the followings; resolving technical problems for streaming, considering how to show the videos and considering about publishing of the inappropriate videos.

【What we found】

Managing and publishing videos is important for second use such as research and education. However there are some problems with publishing the videos. First, we have technical problems caused by the size of video files and a lot of types of video file formats. Secondly, we have to consider how to show the video contents to the viewers. For example, making easy access since finding a video which the viewer wants to see from many video clips takes a lot of time.

Prior to publishing the all videos recorded in TEAMS, we opened a special website (TEAMS Movie Gallery) (Figure 1) publishing some video clips which had been recorded in Otsuchi bay, Yamada bay and Sanriku offshore. Publishing TEAMS Movie Gallery, we chose the video scene and wrote a caption on each video clips, then transcoded the video files for streaming and inserted a watermark in video clips. The size of the video files were very large because most of the video files recorded in TEAMS observations were set to high resolution and high quality. These large video files can not be streamed smoothly due to the network bandwidth shortage. Furthermore, there is a possibility that the video files can not be played smoothly on low spec devices such as tablets and mobile phones because playing a high quality video file needs high machine power. In addition, the viewers have to prepare decoders to play the video files for each file formats. Therefore we have to transcode the original video files to easy to

Figure 1. A screenshot of TEAMS Movie Gallery.

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handle files that are recorded by using same file format like common video streaming web sites.

It is useful for understanding the video contents to classify and write captions of the video scenes. Viewers can find videos in their interest videos faster by the classification categories and captions. Besides, since videos may include inappropriate scenes to be published we carefully managed to publish those videos. We found those videos in the process of classification.

We explained about the status in offshore areas of Tohoku to visitors in a TEAMS event by using TEAMS Movie Gallery. We have received following feedbacks from visitors who saw the videos. Fishermen can use the videos as reference for their fishing, visitors can make use of these videos for understanding off the coast where they live and visitors want to know the depth of the area where the videos were taken.

【Conclusion】

1. Videos can be used for secondary use such as using the videos for another study and understanding the things in the videos by publishing the videos because viewers can understand contents of the videos visually.
2. Before we publish video data, it is necessary to transcode the original video files for streaming.
3. Viewers are able to save the time to find the videos in their interest by keyword search from captions and classification of the video clips.
4. During the classification process, we have to be careful not to inappropriately publish the video scenes which include sensitive information.

【How we investigated】

We sorted the video files by their file formats and size, and timed transcoding the video files before publishing TEAMS Movie Gallery. In addition, we classified the video scenes according to an object and an area which the videos had been taken and clipped appropriate video scenes for publishing from the video files. We wrote captions for each video clips. Table 1 shows file formats, areas, objects in videos, recording time and amount of all video files that we have. Figure 2 is a screenshot of a real video file.

It turns out that we have to transcode the original video files efficiently because we found the transcoding time was five to six times as much as recording time of the video file in the case of Apple ProRes 220Mbps; it takes long time to transcode.

Table 1. Classification of the videos that were taken in TEAMS observations.

Item	Description
File formats	Apple ProRes 220Mbps, H.264/AVC 40Mbps, DV 24.4Mbps, etc.
Areas	Otsuchi bay, Yamada bay, Sanriku offshore, Iwate offshore, Miyagi offshore, etc.
Objects in videos	species (squids, crabs, fish, feather stars, shellfishes, etc.), woods, wrecks, tsunami rubbles, fishing tools, rocks, etc.
Recording time	237 : 20
Amount of all video files	8.2TB

ROV (Remotely Operated Vehicle)
A ROV is an underwater device to obtain the deep sea data. A ROV is lowered from a research vessel and operated by a crew on a vessel via a cable. A ROV has some cameras and sensors. A ROV can take videos and photos, and record water temperature, water pressure, etc.

Lander
A lander is a device which is set on the bottom of the sea for a long time for monitoring the deep sea. As with a ROV, a lander can take videos and photos, and record environmental data in the deep sea.

Apple ProRes, H.264/AVC, DV
Apple ProRes, H.264/AVC and DV are standards for compressing digital videos. These standards can make smaller video files without decreasing video quality.

Decoder
A decoder is a software that decompress an encoded video. For example, it needs a decoder for H.264/AVC to play a video compressed by H.264/AVC.

Bitrate
Bitrate is the number of bits that are processed per second. For example, in the case of that bitrate is 220 Mbps, the number of bits per second in the video data is
220 * 60 = 13,200 Mbit.

Figure 2. A screenshot of a real video.

【Further readings and information】

TEAMS Movie Gallery

http://www.i-teams.jp/gallery/j/index.html

On TEAMS Movie Gallery, we publish the video clips that are especially interesting. We are going to publish all videos apart from this web site.

Outreach activities of Projet Grand Maillet (PGM)

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Key words: PGM, Symposium, Monitoring, Otsuchi, Maillet letter

【Background】

A group of scientists belonging to Atmosphere and Ocean Research Institute, the University of Tokyo (AORI) have done a considerable works at Otsuchi Bay since 60th. Otsuchi is a name of a town locating in the middle of coastal area in Iwate Prefecture. The name means “big mallet” in English and “grand maillet” in French. So the nickname of this project is Projet Grand Maillet (PGM). PGM has used International Coastal Research Center (ICRC), Atmosphere and Ocean Research Institute, which was founded in 1973 in the town, as a base for research in the area. For the research at ICRC, helps by fishermen and the town have been indispensable. Although ICRC was almost completely destroyed on March 11, 2011, AORI quickly decided to rebuild ICRC in the town and continue research in the area, because AORI considered that it is not only for conducting science, but also helping the restoration of the town through scientific activities.

【Aim】

Contribute to the recovery of Otsuchi town, especially fisheries through various types of scientific activities.

【What we did】

It is not always easy for scientists to contribute to the recovery and development of local community. In order to accomplish our aims, at least three conditions have been required. First, the data obtained is not for scientists but rather for local people. Second, the scientific data should be made available to people including fishermen. Third, the implication of scientific data should be explained to people, especially local fishermen with plain words.
Because AORI has a tradition of seeking basic sciences, these conditions were quite challenging.

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PGM then has hired some people for public relations and done the following activities.

1) Providing monitoring data to fishermen

PGM set the five different sensor buoys in Otsuchi Bay (Fig. 1). The data sets obtained are continuously monitored at ICRC and made available for local people or scientists through internet. Now many fishermen are able to see the data by their cell phone every day. This is especially important because sudden intrusions of cold Oyashio or warm Kuroshio currents change the environmental condition drastically and bring completely different organisms. Such information is quite important for fishermen.

Therefore, these monitoring sensors with data distribution are well appreciated by local people.

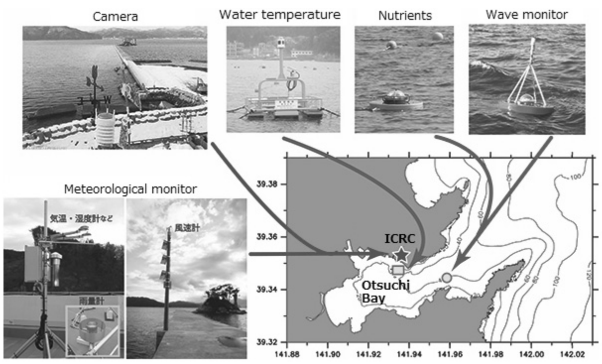

Fig. 1. Monitoring system in Otsuchi Bay

Scientific data are deposited and made available in our “Research Information and data Access Sites of TEAMS (RIAS)” although more efforts to improve this site is required.
Site: http://www.i-teams.jp/catalog/rias/e/index.html

2) Transfer of our knowledge to people through Meetings, symposia and publications

The scientific data obtained have been presented at scientific society conferences and published as scientific papers. However, other types of activities are necessary for transferring our knowledge to people. The followings have been conducted.

・Meeting with local school students

In Otsuchi Town, there are five primary schools; Otsuchi, Ando, Otsuchi-Kita, Akahama and Kirikiri, two junior high schools; Otsuchi and Kirikiri, and Otsuchi High School. Scientists, especially those belonging to ICRC often visit those schools and give lectures.

・Meeting with fishery people

Since 2012 summer, “Salmon café” has been organized every year. The purpose of this meeting is the mutual exchanges of scientific information and experiences of salmon fisheries among scientists, fishermen and local government people. In Iwate Prefecture, there used to be 28 hatcheries for salmon. In fall to winter, salmon were caught at the mouth of rivers, brought to hatcheries where fertilization, hatching and cultivation are conducted until release to river. Approximately, 430 million juveniles had been released every year from those hatcheries. Because most of them were destroyed by the tsunami and the salmon fisheries have been seriously damaged, the “salmon café” has offered important occasion for exchanging related information among the participants and figuring out appropriate direction of the fisheries. In addition to this café, scientists have close connection with fishery people especially those belonging to Shin-Otsuchi Fishermen’s Union. For instance, in response to fishermen’s request, scientists conducted research on water current in Kamaishi Bay, bottom profile in Otsuchi Bay, and so on.

Fig. 2. Salmon Café held in Sept. 2012

・Meeting with local people

Every year, meeting or exhibitions were organized in Otsuchi Town, either at town hall or at shopping center, MAST. Results of research were explained with simple words, panels were presented and some specimens were shown. They offered a good chances to meet and talk with local people. Also, when research vessel, Shinsei maru (joint usage by JAMSTEC and AORI) anchored in Otsuchi Bay, ceremonies with the town and town people were held, because the mother port of R/V Shinsei maru is Otsuchi.

・Symposia

The knowledges we have obtained are scientifically important. Therefore, members presented their papers at scientific societies and also organized symposia at The Oceanographic Society of Japan, The Japanese Society of Fisheries Science and so on.

・Maillet letters

Because general scientific reports or papers are too difficult to be understood by local people, Maillet letters have been published since October 1, 2014. The latest one is the 5th one published in February 2016. It contains explanations of what we found in the marine environments, interviews to local people and scientists, and so on. They are distributed to local town, schools, local government, fishermen’s union.

Fig. 3. The first issue of Maillet Letter published in Oct. 2014. This photo was taken from ICRC in Otsuchi town. The name of the island is Horai-jima.

【Conclusion】

Although this project is for basic research on the change of ecosystems in Tohoku area after the earthquake and tsunami in March 2011, it has a mission to support local people, especially fishermen through scientific activities. Therefore, efforts have been made to transfer our knowledges to people through various ways. We believe that this kind of efforts will be necessary for not only science after the disasters, but also for any

【Further readings and information】

The official website of PGM is as follows:
http://teams.aori.u-tokyo.ac.jp/?lang=english

7. Key word index

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9. About the Book

This book was published at the occasion of "International Symposium on Restoration after Great East Japan Earthquake -Our Knowledge on the Ecosystem and Fisheries-" which was held from 2 to 4th, March, 2016 at Yayoi Auditorium in the University of Tokyo. The contributed papers are results of research under TEAMS Project and presented at the symposium. Masato Hirose and Sheryl O. Fernandes checked all the manuscripts for formatting.

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