

Future Strategy for Marine Biological Research (Summary)

1. Background

Following the compilation of the report entitled “Strategy for Research Relating to Marine Bio-resources” by the Marine Biological Committee, Subdivision on Ocean Development in 2011, MEXT and other agencies have been promoting various initiatives in this regard. With a significant period of time now having elapsed since the publication of the original report, a review has been undertaken of Japan’s medium- and long-term strategy in regard to marine biological research, taking into account the changes in the overall environment for marine research (and particularly marine biological research) in Japan and the changing international situation, with the aim of examining the current status of the measures that have been implemented to date and identifying the key issues that have emerged.

2. Measures relating to research on marine bio-resources – Current status and key issues

The major initiatives that have been implemented since FY2011 by MEXT and other agencies are listed below, with an overview of the current implementation status and with the key issues that have been encountered identified.

(1) Tohoku Ecosystem-Associated Marine Science (TEAMS) Project

The Great East Japan Earthquake of 2011 caused immense damage to the Pacific Coast districts of the Tohoku region, and also to offshore waters, etc. The Tohoku Ecosystem-Associated Marine Science (TEAMS) project has involved the implementation of various measures directly linked to the region’s recovery, and has been carried out in close collaboration with local communities; the results achieved have been very impressive, unmatched by any similar scheme elsewhere in the world. The priority in the future with regard to the results achieved in the TEAMS project and the new research methods that have been developed (involving close collaboration with local communities) is to ensure the continuation of the implanting in the local community of the know-how etc. developed through TEAMS through the use of clear, explicit messages and taking into account the needs of the period after 2020 (by which time the

“Reconstruction and Revitalization Period” will have ended), and also to encourage the adoption of similar methods in other parts of Japan and overseas.

(2) Advancements in Marine Bio-resource Conservation Techniques

Starting from 2011, long-term, systematic survey-based research has been undertaken to develop a more comprehensive understanding of marine ecosystems, along with research aimed at developing revolutionary production technology that pays greater attention to the biological functioning etc. of marine organisms; as implementation of these research plans has progressed, impressive progress has been made. To ensure that the results of this research are used to make a positive contribution to society, there is a clear need for continuing research and for the dissemination of the research results so that they can be implemented in society, focusing on the development of revolutionary cultivation methods for juvenile bluefin tuna, and on the development of a comprehensive understanding of marine ecosystems, etc.

(3) Development of Observation and Monitoring Technology

Beginning in 2011, the R&D work on core technologies that can contribute to the conservation and regeneration of marine biodiversity and marine ecosystems that has been undertaken by the Japan Science and Technology Agency (JST) has led to the development of many advanced new technologies that have a great deal to offer. It is important that, looking ahead to the future, these kinds of technologies are widely adopted and utilized.

(4) Cultivation of Human Resources and Dissemination of Information, etc.

Efforts to cultivate young research talent through their participation in research projects – particularly in areas that have been affected by natural disasters – are very important from the perspective of regional recovery and regeneration. It is vitally important that the future development of marine biological research involves the active recruitment and cultivation of young researchers, as well as their participation in international projects, etc., and other measures to cultivate human talent capable of operating effectively on the global stage. Ongoing outreach activities to disseminate research results in a way that makes them easy to understand are also of great importance.

3. Future Strategy for Marine Biological Research

The following proposals are put forward regarding the approach that should be adopted in the future with regard to the development of marine biological research of strategic importance focused on key issues.

(1) The Pressing Need for, and Vital Importance of, Comprehensive, Integrated Marine Biological Research

With the international debate regarding governance of the oceans growing increasingly serious, there is a need for Japan to be able to influence the course of these international discussions on the basis of sound scientific knowledge. To this end, we need to develop a scientific understanding of the changes affecting marine ecosystems, and in order to achieve a comprehensive understanding of these changes we need to clarify the relationship between the changes and data on climate change, resource renewal, and the impact of human activity; clarification of the quantitative and dynamic changes affecting marine organisms, and an understanding of the reasons for these changes, can support the making of useful forecasts. In order to realize this goal, a comprehensive, integrated approach is needed that embraces a wide range of different disciplines, including the humanities and social sciences, with measures to foster research that provides core, fundamental scientific knowledge able to supply scientific evidence, and which takes into account differing needs.

(2) Strengthening International Collaboration and International Initiatives

Research aimed at identifying, analyzing and forecasting marine bio-resources and marine ecosystems is directly linked to the international debates regarding governance of the oceans; measures are needed to support necessary international collaboration and international initiatives and strategies. There is also a need to develop closer links with other Asian nations and with the island countries of the Pacific; Japan should be demonstrating active leadership in these regions.

(3) Strengthening the Development of Integrated Observation and Monitoring Technology, and Strengthening Research Infrastructure

Organizations such as the Japan Science and Technology Agency (JST) have achieved significant results in the development of many new types of observation technology; it is important to combine fundamental technologies of this kind so that they can be transferred effectively to the private sector and the technologies

adopted widely in society as a whole; at the same time, it is vitally important that measures be implemented to maintain, safeguard and renew the research infrastructure, including research vessels and laboratory equipment, etc.

(4) Establishment of Systems for the Quantitative, Dynamic Recording, Analysis and Forecasting of Marine Biological Data

There is a real need for the establishment of a framework that will permit the sharing of marine biological data deriving from research undertaken for different purposes (which in the past has not necessarily been shared effectively), and for the development of applications that will allow important data to be absorbed and utilized effectively. It is very important to facilitate the layering, integration and analysis of the advances made in information science technologies in recent years along with the wide variety of data relating to marine ecosystems; there is a clear need for the development of suitable marine biological databases that give due consideration to linkage and coordination with earth observation data.

(5) Strengthening Measures that Make Effective Use of the Vitality of Local Communities

In the Tohoku Ecosystem-Associated Marine Science (TEAMS) project, besides the researchers, representatives of local government authorities, fishing industry organizations etc. have been involved in the project right from the planning stage, working together to ensure that the measures implemented function properly. In the future, the results achieved through this approach should be utilized in other projects to the maximum possible extent, utilizing close collaboration with other related parties and implementing measures that make full use of the vitality and capabilities of local communities. After identifying areas in which projects rooted in the local community can be conducted as “model districts,” once the effectiveness of these measures has been verified, the scope of application can be expanded to other parts of Japan, and eventually the ideas in question can be disseminated widely throughout the world.

(6) Cultivation of Human Talent Capable of Operating Effectively on the Global Stage, and Efforts to Enhance Japanese Citizens’ Understanding of the Ocean

To ensure steady forward progress in the development of marine biological research, the cultivation of human talent capable of operating effectively on the international stage is very important. It is also important for researchers to set themselves high standards, strive for meaningful research results, and endeavor to ensure that these research results are disseminated widely throughout society.

(7) Using Marine Biology as a Source for Innovation

In the area of marine biology and genetic resources R&D, there is a need for the effective integration of different technologies, including methods for accessing extreme environments, sample cultivation and preservation technology, genome decoding technology, bio-informatics etc., and for the implementation of these technologies in industry and society as a whole, along with effective intellectual property management, etc. Rather than having these measures restricted to specific institutions, it is important to realize effective coordination across multiple relevant organizations, and consideration should be given to putting in place a framework that will allow Japan's overall national capabilities in this area to be effectively utilized.

Future Strategy for Marine Biological Research

August 27, 2015

Marine Biological Committee

Subdivision on Ocean Development, Council for Science and
Technology

Contents

| | |
|--|----|
| List of Members of the Marine Biological Committee, Subdivision on Ocean Development, Council for Science and Technology..... | 1 |
| Review Process for this Report (the 7 th to 11 th Meetings of the Marine Biological Committee) | 2 |
| Introduction..... | 3 |
| Chapter 1 Background | 3 |
| Chapter 2 Measures Relating to Marine Biological Research etc. - Current Status and Key Issues..... | 6 |
| (1) Tohoku Ecosystem-Associated Marine Science (TEAMS) Project | 6 |
| (2) Advancements in Marine Bio-resource Conservation Techniques..... | 6 |
| (3) Development of Observation and Monitoring Technology..... | 7 |
| (4) Others (Cultivation of Human Resources, etc.) | 7 |
| Chapter 3 Future Strategy for Marine Biological Research..... | 8 |
| (1) The Pressing Need for, and Vital Importance of, Comprehensive, Integrated Marine Biological Research..... | 8 |
| (2) Strengthening International Collaboration and International Initiatives | 8 |
| (3) Strengthening the Development of Integrated Observation and Monitoring Technology, and Strengthening Research Infrastructure | 9 |
| (4) Establishment of Systems for the Quantitative, Dynamic Recording, Analysis and Forecasting of Marine Biological Data | 10 |

| | |
|--|----|
| (5) Strengthening Measures that Make Effective Use of the Vitality of Local Communities | |
| | 11 |
| (6) Cultivation of Human Talent Capable of Operating Effectively on the Global Stage, and Efforts to Enhance Japanese Citizens' Understanding of the Ocean | |
| | 11 |
| (7) Using Marine Biology as a Source for Innovation..... | 12 |

List of Members of the Marine Biological Committee,
Subdivision on Ocean Development, Council for Science and
Technology

Temporary Committee Members:

KUBOKAWA Kaoru, Professor, Misaki Marine Biological Station, School of Science, The University of Tokyo

TAKIZAWA Minako, Science Journalist

TATEYAMA Haruko, Professor, Department of Life Science & Medical Bioscience, School of Advanced Science and Engineering, Faculty of Science and Engineering, Waseda University

NAKATA Kaoru, Research Director, Research Management Department, Japan Fisheries Research Agency (FRA)

Expert Committee Members:

KIMURA Shingo, Professor, Graduate School of Frontier Sciences, The University of Tokyo

KITAZATO Hiroshi, Director, Project Team for Analyses of Changes in East Japan Marine Ecosystems, Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

(Heads)TAKEUCHI Toshio, President, Tokyo University of Marine Science and Technology

NISHIDA Mutsumi, Vice President, University of the Ryukyus

WADA Tokio, Executive Director, Fisheries Research Agency

Review Process for this Report

(the 7th to 11th Meetings of the Marine Biological Committee)

- 7th Meeting (May 21, 2015)
 - Discussion Regarding the Strategy for Marine Biological R&D

- 8th Meeting (June 9, 2015)
 - Discussion Regarding the Strategy for Marine Biological R&D
 - ◇ Hearing Regarding Related Measures
 - KIJIMA Akihiro (Professor, Graduate School of Agricultural Science, Tohoku University)
 - YOSHIZAKI Goro (Professor, Department of Marine Biosciences, Tokyo University of Marine Science and Technology)
 - WATANABE Yoshiro (Professor, Atmosphere and Ocean Research Institute, The University of Tokyo)
 - TAKAHASHI Motomitsu (Senior Researcher, Seikai National Fisheries Research Institute)
 - FUJIKURA Katsunori (Director, Department of Marine Biodiversity Research, JAMSTEC)

- 9th Meeting (June 25, 2015)
 - Discussion Regarding the Strategy for Marine Biological Research
 - ◇ Hearing Regarding Related Measures
 - Fisheries Agency
 - Ministry of the Environment
 - Japan Science and Technology Agency
 - Discussing Regarding the Strategy for Marine Biological Research (Skeleton Plan)

- 10th Meeting (July 23, 2015)
 - Discussion Regarding the Strategy for Marine Biological Research (Proposal)

- 11th Meeting (August 27, 2015)
 - Discussion Regarding the Strategy for Marine Biological Research (Proposal)

Future Strategy for Marine Biological Research

Introduction

The *Basic Act on Ocean Policy* (promulgated in April 2007) and the *Basic Plan of Ocean Policy* (which was approved at a Cabinet meeting held in April 2008; a new *Basic Plan* was subsequently approved at a Cabinet meeting held in April 2013) note the importance of conserving the biodiversity of the oceans; reflecting this, and also the impact of the Great East Japan Earthquake that occurred in March 2011, the Marine Biological Committee, Subdivision on Ocean Development, Council for Science and Technology, Ministry of Education, Culture, Sports, Science and Technology (hereinafter referred to as “the Committee”) compiled a report entitled “Strategy for Research Relating to Marine Bio-resources” in September 2011, and put forward proposals regarding measures etc. that should be implemented by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and related research institutes.

Responding to this report, MEXT and other related organizations made supporting recovery from the Great East Japan Earthquake of 2011 a key priority in the formulation of government policy regarding marine biological research, a stance reflected in the establishment of new projects such as the Tohoku Ecosystem-Associated Marine Science (TEAMS) project, which was aimed at using measures based on scientific knowledge to support the recovery of the fishing industry. Four years have now passed since the Great East Japan Earthquake, and steady progress has been made in the various related projects. Starting from FY2016, the “Concentrated Reconstruction Period” will come to an end and a new “Reconstruction and Revitalization Period” will begin. Over the last few years, there has been a steady increase in concern, both in Japan and overseas, regarding marine organisms and ocean ecosystems, viewed in terms of the fishing industry, ocean environment conservation, development of seabed resources, and collection of marine data, etc., and efforts have been made to improve technologies relating to observation, monitoring, simulation and forecasting; at the same time, there have been dramatic changes in the wider environment. Given these trends, it is clear that the time has come for a new examination of what constitutes an appropriate Future Approach for Japan’s marine biological research activities.

To this end, the Committee has held hearings attended by representatives of MEXT and other agencies involved in the implementation of the measures referred to above, as well as by representatives of other government agencies that are closely linked to the issues concerned, such as the Ministry of the Environment and the Fisheries Agency of the Ministry of Agriculture, Forestry and Fisheries (MAFF); the proposals presented here have been formulated on the basis of the

discussion at these hearings, and of examination of the policy measures that should be prioritized in the future, and of suitable approaches for coordination and communication between relevant agencies.

Chapter 1 Background

The Positioning of Marine Biological Research within the *Basic Plan of Ocean Policy* etc.

The *Basic Act on Ocean Policy* which came into effect in April 2007 noted that “it is important to realize a new oceanic State in harmonization of the peaceful and positive development and use of the oceans with the conservation of the marine environment.” The *Basic Plan of Ocean Policy*, which was based on the *Act*, was formally approved at a Cabinet meeting held in April 2008. A new, revised *Basic Plan* was subsequently approved at a Cabinet meeting in April 2013. While continuing to emphasize the importance of the “promotion of marine surveys and integration and disclosure of marine-related information,” the revised *Basic Plan* also stresses the need to strengthen observation and survey-based research etc. aimed at clarifying the interaction between the oceans and the atmosphere, the ocean cycle and the accompanying heat transfer and carbon cycles, the increase in ocean acidification resulting from the increased quantities of carbon dioxide being absorbed by the oceans, and the impact of these various factors on marine ecosystems, as a requirement for comprehensive, systematic policy implementation. The *Basic Policy on Economic and Fiscal Management and Reform 2015*, which was approved at a Cabinet meeting in June this year, includes measures aimed at responding to the impact of climate change, along with measures relating to the use of forests to absorb carbon dioxide, etc., and also stresses the need to promote greater understanding of climate change issues among the general public.

Growing Concern in the International Community Regarding the Need for Ocean Governance that is Based on Scientific Knowledge

Turning to the situation overseas, one of the three key themes included in the “G-Science Academies Joint Statement” issued by the national science academies of the G7 (Group of Seven) countries in April this year was the “Future of the Ocean: Impact of Human Activities on Marine Systems”; the Joint Statement called for: (1) changing the course of nations’ CO₂ emissions, (2) reducing and further regulating man-made pollution of the sea, (3) ending overfishing and preserving marine biodiversity and ecosystem function through research-based management and (4) enhancing international scientific cooperation to better predict, manage and mitigate future changes in the ocean, and their impacts on human societies and the environment. On the basis of this Joint Statement, the need for “protection of the marine environment” was noted in the Leaders’

Declaration at the G7 Summit in June 2015; the G7 committed itself to priority actions and solutions to combat marine litter (particularly plastic litter), and to the adoption of a precautionary approach to deep-sea mining activities, as well as the conducting of environmental impact assessments and scientific research.

Regarding the Sustainable Development Goals (SDGs), which are under consideration for possible adoption by the UN General Assembly in September this year, one of the 17 goals noted in the Report of the Secretary General that was published in December last year (following collation by the Open Working Group (OWG) established by the UN) is to: “Conserve and sustainably use the oceans, seas and marine resources for sustainable development.” The SDGs attach great importance to the implementation by all countries (including the advanced nations) of effective measures, based on solid scientific evidence, that are aimed at sustainable development, and to the establishment of appropriate governance.

Within the framework of the United Nations Environment Programme (UNEP), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is engaged in compiling assessment reports on biodiversity and ecosystem services in coastal regions throughout the world. With support from the Japanese government, the Technical Support Unit (TSU) for the compilation of the assessment reports for the Asia Pacific region has been located in Tokyo. In addition, a more comprehensive global oceans assessment report is scheduled to be published in December this year within the framework of the United Nations Convention on the Law of the Sea (UNCLOS).

Based on climate change forecasts covering the period up until the middle of the 21st century and the period after that, the IPCC Fifth Assessment Report (AR5), which was published in 2014, notes issues relating to changes in the global distribution of marine organisms and relating to the impact on the continued provision of ecosystem services (such as fisheries productivity) of the reduction in biodiversity in ocean regions that are particularly vulnerable to the impact of climate change.

Regarding the safeguarding of marine biodiversity and sustainability outside countries’ territorial waters, in June 2015 the UN General Assembly adopted a proposal that talks should begin in regard to the compilation of an internationally binding document within the framework of UNCLOS. Future talks in this area will address the issue of marine genetic resources (MGR) (including questions relating to the allocation of benefits), regional management tools such as marine protected areas (MPAs), environmental impact assessments, capacity building, marine technology transfer, etc.

Discussions are also progressing regarding international observation networks. The Argo project¹, an international scientific project to build a system for monitoring the condition of the oceans in real

¹ The Argo project is an initiative driven by collaboration between international organizations such as the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), and organizations in various countries, which involves the ongoing development of a global array of free-drifting temperature/salinity profiling “Argo floats” covering the upper 2,000m of the ocean. As of July 2015, a total of approximately 3,800 Argo floats were operating.

time on a global scale, which involve collaboration between the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) and other international organizations, along with organizations in various countries, has made a major contribution to research in the fields of climate change and physical oceanography. Currently, international discussions are underway regarding the possibilities for further expanding the project with the development of “next-generation” Argo floats, including “Bio Argo” floats equipped with sensors that would be able to obtain accurate information about marine organisms, and “Deep Argo” devices able to carry out monitoring in the deep sea.

There is also growing concern in industry, etc. For example, in 2014 the Global Ocean Commission (GOC), an association of senior international experts, issued a report entitled “From Decline to Recovery – A Rescue Package for the Global Ocean,” which recommended improvements in the governance of the high seas so as to help safeguard marine biodiversity and promote regeneration. The World Ocean Council (WOC), an alliance of companies and groups involved with ocean-related industries, has organized discussions regarding the links between industry and marine policy, etc., and in 2015 organized an international summit on the theme of “Sustainable Development and Growing the Blue Economy – the Next 50 Years,” at which presentations were given by leading international figures in ocean-related sectors.

It can thus be seen that, over the past few years, there has been lively international discussion, from many different perspectives, regarding the sustainable use of the oceans. However, by comparison with our knowledge of the land, human scientific knowledge in regard to the oceans is still inadequate. There is growing awareness of the need to enhance overall scientific knowledge of the oceans (including marine organisms and marine ecosystems), and of the need to strengthen monitoring, appraisal and data-sharing, etc.

Moving from the “Concentrated Reconstruction Period” into the “Reconstruction and Revitalization Period”

Regarding the recovery from the effects of the Great East Japan Earthquake of 2011, the Japanese government set a reconstruction timeframe of 10 years; given the need to help areas affected by the disaster to achieve restoration and recovery as soon as possible, the first five years of this timeframe were positioned as the “Concentrated Reconstruction Period,” and a variety of measures have been implemented during this period. Today, more than four years have elapsed since the earthquake, and the beginning of the “Reconstruction and Revitalization Period” is now approaching. With the aim of ensuring that reconstruction projects can be successfully completed as soon as possible, measures are being implemented to achieve results from relevant survey and research projects at an early stage, so that they can be applied to projects aimed at the recovery of the areas affected by the disaster. There is a need to further accelerate survey and research projects, and to undertake research the results of

which will contribute directly to recovery and regeneration.

Contributing to a Better Understanding for the Development of Fisheries Resources

The Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries (MAFF), is the government agency most closely involved with fisheries resources policy. In accordance with the *Fisheries Basic Act* (which was promulgated in 2001) and the *Basic Plan for Fisheries*, the Fisheries Agency, working mainly through the Fisheries Research Agency (FRA), has been implementing (on an ongoing basis) technology development etc. contributing to ensuring the stable supply of aquatic products and to the healthy development of the fisheries sector. In recent years, with the continued increase in the global population and with the impact of climate change, etc., there has been a worldwide increase in instability in regard to the supply of food, raising issues relating to the enhancement of food self-sufficiency and the stable supply of food. The *New Basic Plan for Agriculture, Forestry and Fisheries Research* (formally approved on March 31, 2015) aims to promote measures to address these issues. There is a need for fundamental research and development work focusing on the structure and functions of ecosystems, clarification of the mechanisms which cause these to change, and how ecosystems respond to climate change, etc.

Contributing to a Better Understanding of Marine Ecosystems

The Ministry of the Environment (MOE) has formulated the *National Biodiversity Strategy of Japan 2012 - 2020* based on the *Basic Act on Biodiversity* (which came into effect in 2008), and the Biodiversity Center of Japan has been carrying out ongoing surveys aimed at developing a clear picture of the current state of Japan's natural environment and ecosystems. Tidal flats, seaweed beds, coral reefs and other areas of shallow water play a very important role in safeguarding biodiversity; the establishment of marine protected areas (MPAs) is necessary to ensure appropriate conservation management. However, biodiversity is at risk because of global warming and other aspects of human activity. Responding to this situation, over a five-year period beginning in 2011 the MOE has been using the Environment Research and Technology Development Fund to carry out the Integrative Observations and Assessments of Asian Biodiversity research project, including quantitative assessment and forecasting of the loss of biodiversity in marine ecosystems. In the future, more work will be needed to expand fundamental knowledge so as to contribute to the safeguarding of biodiversity and the establishment of MPAs.

Chapter 2 Measures Relating to Marine Biological Research etc. - Current Status and Key Issues

Starting in FY2011, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been implementing two major projects: the Tohoku Ecosystem-Associated Marine Science (TEAMS) project, aimed at supporting recovery from the effects of the Great East Japan Earthquake of 2011, and the Advancements in Marine Bio-resource Conservation Techniques project, intended to foster the expansion of knowledge of marine ecosystems, clarify how they function, and support the development of revolutionary new marine production technology. The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been making effective use of its world-class deep sea access technology etc. to implement marine life science research; the Japan Science and Technology Agency (JST) has been undertaking the Establishment of Core Technology for the Preservation and Regeneration of Marine Biodiversity and Ecosystems as one research area within the JST Strategic Basic Research Programs, and has been carrying out R&D on advanced technology, etc.

The current status of these projects, and the issues faced, are outlined below.

(1) Tohoku Ecosystem-Associated Marine Science (TEAMS) Project

The Great East Japan Earthquake of 2011 and the tsunami that accompanied it caused large quantities of debris to flow out into the sea and caused severe damage to seaweed beds and tidal flats, etc.; the fisheries sector in the Pacific Coast districts of the Tohoku region suffered severe damage. Key issues that needed to be tackled to support the recovery of the fisheries sector in the areas affected by the disaster included long-term surveys of the changes in the environment of fishing grounds and aquaculture facilities, and in marine ecosystems, as well as the development of new types of business operation that make effective use of the region's fisheries resources. To this end, Tohoku Ecosystem-Associated Marine Science (TEAMS) was established to create a network for universities, research institutes etc. to support the recovery process. The specific projects being implemented include the five-year Technology Development to Support the Creation of New Industries project, and the ten-year Marine Ecosystem Research project.

In the Technology Development to Support the Creation of New Industries project, the aim is to use nascent technologies developed by universities etc. to support the growth of new industries in the disaster-affected areas. Universities and research institutes have been working closely with local enterprises etc., tackling eight issues, including production of high-quality seaweed, development of new materials and bioethanol etc. from previously unused resources, and the commercialization of new technologies relating to refrigeration and freezing methods to

keep marine products fresh and maintain their quality. Working together with local fishermen's associations, etc., significant results have already been achieved in regard to the establishment of systems for sustainable production of Sargassum, commercialization of advanced refrigeration technology for shellfish, and technology for the rapid analysis of pollution status, etc. Important new developments can be anticipated in the industries making use of these technologies in the future.

The Marine Ecosystem Research project has brought together researchers from throughout Japan, in particular from three key institutions: Tohoku University; Atmosphere and Ocean Research Institute, The University of Tokyo; and Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Project implementation has made effective use of linkages with local government authorities etc., and of collaboration between researchers in different fields, including not only marine biologists but also researchers in the areas of physical oceanography, chemical oceanography, marine geoscience, etc. The project has already produced many significant results which are contributing to the recovery of the fisheries sector, including research on debris distribution, development of new fishing methods for use in fishing grounds affected by debris, surveys aimed at boosting the salmon return rate and research that helps to expand knowledge of the factors affecting this, etc. Monitoring has also been carried out using a combination of different methods, and the results have been shared with the region's citizens; the research methods adopted for the project, which involve making effective use of data archiving and database utilization in response to disruption in the marine environment, have much to offer. In the future, more research will be needed which makes use of the vast amount of data that have been collected, with the utilization of more advanced resource volume forecasting techniques and the establishment of efficient cultivation methods, so as to generate outcomes with higher value-added. Given that the recovery of the marine ecosystems is a long-term process, and that recovery efforts on land may affect it, there is also a need for continued, ongoing survey work. The priority in the future with regard to the results achieved in TEAMS and the new research methods that have been developed (involving close collaboration with local communities) is to ensure the continuation of the implanting in the local community of the know-how etc. that has been developed, through the use of clear, explicit messages and taking into account the needs of the period after 2020 (by which time the "Reconstruction and Revitalization Period" will have ended), and also to encourage the adoption of similar methods in other parts of Japan and overseas.

(2) Advancements in Marine Bio-resource Conservation Techniques

Implementation of the Advancements in Marine Bio-resource Conservation Techniques project began in 2011, focusing on long-term, systematic survey-based research aimed at

developing a comprehensive understanding of marine ecosystems, and the development of revolutionary new production techniques that take into account the physiological functioning etc. of marine organisms. Three key topics were selected for implementation: “Development of a Novel Method to Produce Bluefin Tuna Gametes Using Germ-line Stem Cell Manipulation,” “Research on the Regeneration, Conservation and Sustainable Utilization of Bio-resource Productivity Based on Coastal Ecosystem Complex Adjustment Mechanisms,” and “Clarification of the Kuroshio Current Adjustment Mechanism that Support Fisheries Production in Japan.” Significant progress and meaningful results have already been achieved in this project. In the future, to ensure that the research results can be utilized effectively by society, there will be a need for ongoing research aimed at the adoption of the revolutionary new methods for juvenile bluefin tuna cultivation and at a comprehensive clarification of the functioning of marine ecosystems, as well as effective dissemination of research results for implementation in society.

(3) Development of Observation and Monitoring Technology

In order to expand basic data and knowledge regarding the oceans, long-term, systematic monitoring of the distribution and density of marine organisms (and of how these change over time) is vitally important. Due to the difficulties involved in securing access to the ocean from the land, the great depths to which the oceans extend, and the wide area over which marine organisms travel, etc., marine research requires highly advanced technology.

Research and development work has been progressing steadily in areas such as manned submersibles, unmanned exploration vessels, DNA bar-coding, metagenomics, high-precision analysis technology using bio-elemental and stable isotope ratio analysis etc., bio-logging, bio-informatics, satellite remote sensing, etc. Given the expectations among the general public for more effective utilization of the oceans, there is a need for further progress to be made in these areas, and for the development of even more advanced technology. What is particularly vital at this point in time is the implementation of collaborative R&D to bring together researchers in engineering and the life sciences with marine biologists.

Since 2011, the Japan Science and Technology Agency (JST) has been working on the development of advanced technologies as part of its project for the Establishment of Core Technology for the Preservation and Regeneration of Marine Biodiversity and Ecosystems. Steady progress has been achieved in the development of new technology, including biodiversity appraisal and environmental forecasting methods that make use of digital DNA chips, remote identification technology that uses marine organism calls and reflected sounds, construction of mathematical models for environmental risk based on meta-omics analysis of difficult-to-cultivate marine microorganisms using single-cell genomic sequencing data, quantitative monitoring of fish schools based on environmental DNA analysis, and ecosystem

assessment methods, etc. In the future, these types of technology (including automated monitoring) will need to be widely adopted and utilized.

A Japanese team that included the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and private-sector companies came 3rd out of 77 teams in the Accuracy award division in the Wendy Schmidt Ocean Health XPRIZE, an international competition to develop marine pH sensor technology that can be utilized in research on ocean acidification. It is anticipated that this sensor technology will be incorporated into the Argo floats in the future.

(4) Cultivation of Human Resources and Dissemination of Information, etc.

The cultivation of young research talent is vitally important for the achievement of steady progress in marine biological research. When implementing research projects, it is important to actively recruit young research talent in a wide range of fields. In the projects outlined in sections (1) to (3) above, a proactive effort has been made to cultivate young researchers, including graduate students and post-doctoral researchers; particularly in regard to regions that have been affected by natural disasters, efforts to ensure participation in research projects by young research talent are to be applauded, from the perspective of promoting recovery and regeneration. It is also gratifying to see that domestic and international conferences are being used to provide opportunities for exchanging information and ideas with domestic and overseas researchers, technical experts and representatives of the business community, thereby helping to germinate new ideas for future research and development activity. There have also been many instances of collaboration with elementary schools, junior high schools and senior high schools, etc., in which researchers involved in various projects visit schools to give instructional sessions or provide experiential learning opportunities. Opportunities such as this to help schoolchildren develop a greater interest in marine organisms, and to help educators develop a more in-depth understanding of marine biological research, are very important. Other measures that warrant praise include the active implementation of outreach activities aimed at spreading awareness of research results in an easy-to-understand way, such as the holding of presentations for representatives of the fishing industry, the organizing of symposiums open to the general public, and holding open days at which the public can visit research facilities, etc.

Chapter 3 Future Strategy for Marine Biological Research

In light of the current situation for marine organisms and the related social issues, the Commission puts forward the following recommendations as regards the strategy that MEXT should adopt in regard to strategically-important key aspects of marine biological research. In regard to the implementation of the following categories of marine biological research, given the government's budgetary constraints, there is a need to ensure the strengthening of communication and coordination between central government ministries, local government authorities, and research institutes, etc., in order to ensure that research funding is provided as effectively as possible.

(1) The Pressing Need for, and Vital Importance of, Comprehensive, Integrated Marine Biological Research

The last few years have seen increasingly serious international debate regarding best approach to ocean governance for ensuring the sustainable use of the oceans, in regard to such areas as fisheries, biodiversity, development of ocean mineral resources, disaster prevention, etc. As an island nation, there are many areas in which Japan benefits from the oceans, and there is a real need for Japan to play a leading role in international discussions, to ensure that the formulation of international rules and governance strategies is based on scientific knowledge. To this end, it is important not only to develop a scientific understanding of the changes taking place in marine ecosystems, but also to possess the technology required in order to implement ongoing monitoring, analysis and forecasting of these changes. To develop a comprehensive understanding of these changes, besides identifying relationships in the data relating to climate change, resource renewal, and the impact of human activity, it will also be necessary to identify the quantitative and dynamic changes affecting marine organisms, understand the factors behind these changes, and forecast how they will develop over time. In order to realize this goal, a comprehensive, integrated approach is required that embraces a wide range of disciplines (including the humanities and social sciences). MEXT needs to be working together with related ministries and organizations to undertake research to obtain the core scientific knowledge needed to provide reliable scientific evidence, while at the same time taking into account differing administrative requirements.

(2) Strengthening International Collaboration and International Initiatives

Research aimed at monitoring, analyzing and forecasting marine bio-resources and marine ecosystems is directly linked to discussions regarding international rule-making in relation to ocean governance. As such, it is advisable for any necessary international collaboration and international development strategy perspectives to be taken into account right from the planning

stage.

As research relating to marine organisms can involve comparative research examining different parts of the ocean, and given that nutrient salts, harmful substances etc. can be carried from one region to another on the ocean currents, while large marine animals tend to migrate over long distances, collaboration between domestic and overseas researchers is vital. Individual Japanese researchers are already undertaking collaboration with overseas researchers, and progress is being made in the formation of networks that link domestic and overseas research institutes, but there is a clear need for more proactive, systematic international collaboration in the future.

The waters round Japan are a biodiversity hotspot, with around 15% of the world's marine organisms being found there. Japan is also one of the countries whose citizens spend most on the consumption of aquatic products. Research conducted in these waters is important not only in terms of helping to safeguard Japan's food security; it also has global importance, and by expanding human knowledge, research undertaken in these fields can help Japan to exercise leadership within the international community. In regard to the Asia Pacific region (of which Japan forms part), at the 4th APEC Ocean-related Ministerial Meeting, which was held in August 2014 around the theme of a new partnership with Asia-Pacific ocean cooperation, discussion focused on four priority areas: (1) coastal and marine ecosystem conservation and disaster resilience; (2) the role played by the ocean in food security and food-related trade; (3) marine science, technology and innovation; and (4) the Blue Economy. Through frameworks such as this, Japan can build closer links with other Asian nations and with the island countries of the Pacific, and can play an active leadership role in marine biological research within the region. Using the foundation provided by international collaboration and discussion within the research community to make a positive contribution to international governance is very important, and there is also a clear need to undertake cultivation of human resources to support this goal.

It should be noted that the measures adopted by Japan in response to the Great East Japan Earthquake of 2011 have attracted a great deal of attention in the international community; the proactive dissemination of survey results has an important role to play in preventing damage to Japan's international reputation and in maintaining trust. At the same time, careful examination of the disturbance caused to marine ecosystems and the ocean environment by the disaster, and clarification of the mechanisms involved in their recovery over time, is an important subject for academic research in and of itself, and Japan has an international responsibility to disseminate and share the research results with the world, as a "witness to history."

(3) Strengthening the Development of Integrated Observation and Monitoring Technology, and Strengthening Research Infrastructure

The Japan Science and Technology Agency (JST) and other research institutes, etc. are achieving impressive results in the development of many new types of observation technologies. In the future, these sorts of fundamental technologies will need to be combined, and brought into practical use as soon as possible, so that they can be widely adopted in society and transferred to the private sector.

Ongoing, continuous surveys and monitoring are extremely important in marine biological research. There is a clear need for a project framework that will help to invigorate existing projects while also facilitating continued monitoring in new projects. Currently, marine ecosystems are being placed under stress because of global warming, as well as acidification, deoxygenation, and rising sea levels. There is growing need for a global observation system to detect and monitor how marine ecosystems are changing in response to the “compound stress” created by the combination of the above types of stress and stress deriving directly from human activity (such as coast utilization, fisheries etc.), and for the formulation of measures to mitigate these impacts and support ecosystem recovery. An effective approach in this regard would involve a combination of wide-range monitoring networks, using continuous monitoring devices such as Bio Argo floats to measure specific parameters, together with the establishment of time-series data collection points in areas of the ocean that academic research indicates are of particular importance, focusing on long-term change, and taking detailed measurements, including field experimentation that targets multiple bio-parameters. The development of advanced modeling that can make effective use of the observational data accumulated in this way for forecasting purposes is also very important. A further point is that, for research in this field, research infrastructure such as research vessels and experimental facilities etc. plays a very important role. Not only will there be a need to continue ensuring the maintenance and availability of this research infrastructure in the future, active promotion of the shared use of research infrastructure will also be required.

(4) Establishment of Systems for the Quantitative, Dynamic Recording, Analysis and Forecasting of Marine Biological Data

Marine biological related research and surveys are undertaken for various different purposes by universities, local government authorities, research institutes, etc., and the data obtained is not always shared. There is a need for a review and consultation framework that will enable the greatest possible use to be made of the various programs initiated by different organizations for different purposes, aiming for enhanced coordination and maximization of the results achieved. A framework needs to be put in place that will allow related parties to liaise with one another and to

share their separately obtained data, so that cloud-based data that does not form a combined database can be handled using “big data” techniques, along with the development of applications that will enable required data to be accessed and utilized efficiently. This new “database” should not be limited to Japan; consideration should be given to the possibility of achieving international integration. To be able to analyze and forecast how ecosystems respond to change, “qualitative” data that only examines biodiversity in terms of the number of species present is not enough; there is a need to obtain “quantitative, dynamic” data. The ability to undertake integrated analysis of oceanographic data – including data on marine organism distribution and migration, genome data, experimental data on organism growth and activity etc., and data derived from vessels, satellites, buoys, Argo floats, etc. – is very important for the effective implementation of marine bio-resource management (i.e. development and conservation), including efforts to ensure sustainable use of fisheries resources under conditions of global warming.

Coastal areas tend to have a wide variety of different ecosystems. Many species that normally live inland or in the open ocean reproduce and/or spend the early stages of their lifecycle in coastal areas, making these areas particularly important. Being adjacent to land, coastal areas are the ocean areas most directly affected by terrestrial climate and ecosystems and by human activity. Different environments (inland, coastal, and the open ocean) are physically connected through various cycles etc., and resource transfer between ecosystems helps to maintain high levels of biodiversity. In order to fully understand resource renewal in ecosystems, it is vital to have knowledge of the functioning of (and changes in) the dominant species within the ecosystem; at present, this kind of biological knowledge is still lacking, and there is a clear need for further research.

Given that migratory fish species such as tuna and bonito travel over a very wide area, it is vitally important to be able to implement seamless surveys and research that extend from the coast and Japan’s Exclusive Economic Zone (EEZ) out into the high seas. There is thus a need for careful consideration of the strategic framework to be adopted in regard to the scope of data collection, data handling, and maintaining data quality, within the limitations imposed by national budgetary constraints. The ways in which data are handled need reviewing, and consideration should be given to the current trend towards “open data.”

In light of these circumstances, and bearing in mind that the research on marine ecosystems undertaken as part of the MEXT initiatives to develop advanced techniques for the conservation of marine bio-resources is being carried out from a long-term perspective, rather than being expected to produce results in the short term, we need to be aiming for integration with other projects etc. and exploring better approaches, while also considering strategies that meet the needs of Japan’s ocean policy as a whole, with the goal of achieving even better results in future.

The advances made in information technology over the past few years have been spectacular.

These achievements have a very important role to play in relation to the layering, integration and analysis of the diverse range of data relating to marine organisms and marine ecosystems, which constitute highly complex systems. While the development of suitable databases is a very important measure, the Planning and Evaluation Division's Group on Earth Observation has given a particularly high priority to discussion of the integration and effective utilization of earth observation data, and work is underway on the construction of a platform for data integration, including observational data relating to marine organisms; in the future, liaison and collaboration aimed at realize more integrated data collation will be vitally important. It should be noted that, in regard to marine biological related data, the range of survey items is very broad, and the standardization needed to facilitate data comparison is not well advanced; these issues will need to be addressed.

In order to fully understand the impact of human activity on eco-systems and be able to make useful forecasts, not only is it important to ensure that existing observational data is properly archived so that it is available for use in the future, it is also very important to properly maintain and manage specimen data etc. from the past, which records environmental information from periods when the impact of human activity on the environment was expanding. To this end, there is a need for close coordination with social education facilities such as museums and aquariums, which often hold archives of specimen data, etc.

(5) Strengthening Measures that Make Effective Use of the Vitality of Local Communities

The Tohoku Ecosystem-Associated Marine Science (TEAMS) project has demonstrated that, from the point of view of ensuring the efficient collection of marine bio-resource data and the effective utilization of the scientific knowledge thus obtained, having researchers, local government authorities, fishermen's associations and other related parties all participating together in research from the planning stage onwards is a highly effective approach. With TEAMS, thanks to the creation of new "conduits" for communication with local stakeholders and local residents, and thanks to a conscious effort to take local needs into account, it has been possible to create a marine biological research project rooted in the local community of a kind that has rarely, if ever, been seen before. In the future, the results achieved in TEAMS will need to be applied to other projects to the maximum possible extent, working to achieve meaningful collaboration with local universities, local government authorities, business enterprises and fisheries organizations, in line with the goal of regional regeneration. There is also a real need for the creation of a cycle whereby, within a framework in which fisheries organizations, local residents etc. are involved in the implementing of marine observation, the institution implementing the project can receive data and in turn provide high-value-added feedback.

As a first step, "model regions" in which this kind of project that is deeply rooted in the local

community can be developed should be identified for use in pilot projects; the strategy adopted for verifying the efficacy of the approach and for implementing rollout will need to be carefully considered. It is important to ensure that, eventually, this approach can not only be implemented widely within Japan so as to provide real benefits to society from research projects, but can also be disseminated widely overseas.

(6) Cultivation of Human Talent Capable of Operating Effectively on the Global Stage, and Efforts to Enhance Japanese Citizens' Understanding of the Ocean

The cultivation of young research talent is vitally important to ensure the smooth development of marine biological research; it is very important that, when implementing research projects, a proactive effort should be made to recruit young research talent across a wide range of fields. Measures aimed at the cultivation of research talent able to operate effectively on the global stage, such as supporting participation in collaborative international projects, etc., are also vital for ensuring that Japan remains a world-class player in the field of marine biological research. At the same time, given that Japan is an island nation for which the oceans are of great significance, if Japan can take the lead in promoting collaborative international research projects, working actively to play a leading role in marine biological research that relates to international ocean governance and the formulation of relevant rules and guidelines, then this will also make a positive contribution towards the cultivation of research talent able to play an active part in international projects. A further point is the need to encourage active participation by female researchers; for example, consideration must be given as to how to provide support for researchers with childcare responsibilities so that they can take part in field surveys that involve spending extended periods away from home.

Besides the cultivation of researchers, the cultivation of the technical specialists who are required to support ocean monitoring and bio-resource surveys conducted from on board ships is also needed. Training vessels and research vessels operated by universities and maritime vocational schools have an important role to play here, and in the future a concerted effort will be needed to ensure that these resources are in place. Taking steps to promote the effective utilization of marine biological research and fisheries research facilities located in coastal districts should also be a priority. In addition, in order to ensure the future supply of the human talent needed to undertake marine biological research, it is extremely important to ensure that schoolchildren in elementary school and in junior and senior high school have the opportunity to learn about the latest research results in the field of marine biology. Another priority is to increase the number of people enrolling in graduate school in marine biological related courses, to help ensure an adequate supply of research talent in the future; increasing the number of regular (as opposed to short-term) positions available for researchers may be a useful measure in this regard.

It is very important to promote outreach activities that can spread awareness of research results in an easy-to-understand way, not only to people working in ocean-related industries, but also to the general public as a whole (from an “ocean education” perspective). Social education facilities such as aquariums and museums can make an important contribution to educational outreach; not only do they have an important role to play in cultivation of human resources and awareness-raising, they also, increasingly, constitute a valuable tourism resource, and so their promotion should be coordinated with local communities. A proactive effort should be made to utilize ocean-related cultural resources, making effective use of “Marine Day” (a national holiday in Japan celebrated in July) etc. for the holding of events such as open days at research vessels and other ocean-related facilities. It is very important for researchers working in this field to maintain high awareness of the need not only to obtain valuable research results but also to disseminate these results widely within society.

(7) Using Marine Biology as a Source for Innovation

Due to the difficulty in developing genetic resources from the oceans as compared to genetic resources on land, the oceans represent an unexplored “treasure-house” of genetic resources; it can be anticipated that, in the future, useful, as yet unknown genetic resources will be discovered in the oceans. By making use of the special capabilities of micro-organisms etc. living in extreme environments such as the deep oceans, near undersea thermal vents, and in the Earth’s crust under the oceans, etc., where it had previously been assumed that life could not exist, there is the potential for new innovation in a wide range of fields, including medicine, pharmaceuticals, food manufacturing, environmental science, the energy sector, etc.

Besides the direct utilization of genetic resources, researchers (particularly in Europe and North America) are also using marine life as a source of innovation for the design of industrial products etc. based on completely new concepts, through biomimetics.

R&D in the areas of marine organisms and genetic resources requires the use of a combination of different technologies, including methods for accessing extreme environments, sample cultivation and preservation technologies, genome analysis technology, bioinformatics, etc.; it also requires application to society, “bridging” to facilitate applications in industry, and effective knowledge management, etc. With the development of new technologies such as next-generation sequencers, new applications are being opened up for marine organism and genetic resource research. In addition, as summarized by the phrase “open innovation,” proactively welcoming involvement by researchers in different fields, and dismantling the boundaries between disciplines, has the potential to stimulate previously unimaginable innovation; research on marine organisms and genetic resources should not be confined to the marine biological sphere, but should be utilized to stimulate technology development in many

different fields.

Consideration needs to be given to the development of a framework that will facilitate effective collaboration between different organizations, rather than having marine biological research be carried out by individual institutions working in isolation from one another; in this way, the coordinated capabilities of Japan as a whole can be activated. In particular, National Research and Development Agencies such as the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), which possess a wide range of R&D resources, including equipment for accessing the oceans, as well as supercomputers and other computing resources, etc., need to fully embody their new status as National Research and Development Agencies by strengthening their role as hubs for stimulating innovation, with the adoption of a perspective that emphasizes the maximization of research results for marine science research in Japan as a whole, rather than the perspective of the individual institution. Consideration should also be given as to how the funding function of organizations such as the Japan Science and Technology Agency (JST) etc. can be effectively integrated.